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THE EVENING STAR.

THE moon is the nearest world to the earth and the one best known to astronomers. It accompanies us unceasingly in our celestial course, and remains indissolubly attached to our planet, like a faithful satellite, revolving around us at a distance of 240,000 miles. But it is only a satellite, and not a planet. Every one knows that there are eight principal planets that revolve around the sun, the center of our system, and the heart of the immense planetary organism. These eight worlds are, commencing with the one nearest the sun: Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

Mercury gravitates at 37,000,000 miles from the sun; Venus at 69,000,000; the earth at 95,000,000; Mars at 145,000,000; Jupiter at 436,000,000; Saturn at 909,000,000; Uranus at 1,828,000,000, and Neptune at 2,862,000,000.

The nearest planet to the earth, then, is Venus, since between the orbits of the two the distance is only 26,000,000 miles. But she is not so well known as Mars, because when she passes at her greatest proximity to the earth, she is then between us and the sun, so that we do not see her hemisphere, which is enlightened by the latter; while when Mars passes at *his* greatest proximity, we are between the sun and him, so that his enlightened face is turned toward us. But, after the moon and Mars, she is the best known world, although we are able, so to speak, to obtain a good observation of her obliquely only.

She is the most brilliant star of our heavens. When in the evening, after sunset, she has freed herself from the feeble glimmer of the twilight, we see her glittering like a limpid diamond, and arresting the attention of the most indifferent persons by the brightness of her pure white light. She even attains, under certain circumstances, so remarkable a brilliancy that she casts a shadow—a fact that I have several times witnessed in Italy in 1873. At times, too, but more rarely, she becomes visible in broad daylight. She was observed shining in the heavens, in spite of the sun's presence, in 1876, 1868, 1860, and 1852. This phase of greatest visibility returns about every eight years. In 1797 it particularly arrested the attention of Parisians, and that of General Bonaparte himself, returning as a conqueror from the Italian campaign. The appearance of the star was associated with the victories of the French Republic and the rapid fortunes of the young soldier; and perhaps the future emperor was not averse himself to accepting a like association of ideas; and perhaps, too, this coincidence was the origin of his faith in his star. Indeed, he believed that he was guided by a star. One evening, leaning on his elbow at a window of the Tuileries, he appeared to be absorbed in vague contemplation, and was fixedly regarding a point in the starry heavens, when suddenly turning towards Prince Talleyrand, who accompanied him, he said: "Do you see? that is my star! It has never abandoned me. So long as it shines I will have no doubt of success."

The observation of Venus at midday, and with the naked eye, is not so modern as generally supposed. The historian Varro relates, in fact, that "Æneas on his voyage from Troy to Italy saw this planet constantly, in spite of the presence of the sun above the horizon."

Without giving an exaggerated importance to the passage, let us remark that Varro (*fide* St. Augustine) said, in one of his works now lost, that, at an epoch which was already far back of his own time, Venus had changed color and brilliancy. This is quite evidently an error due to the appearance of a comet or of a new star which has been confounded for some days with Venus.

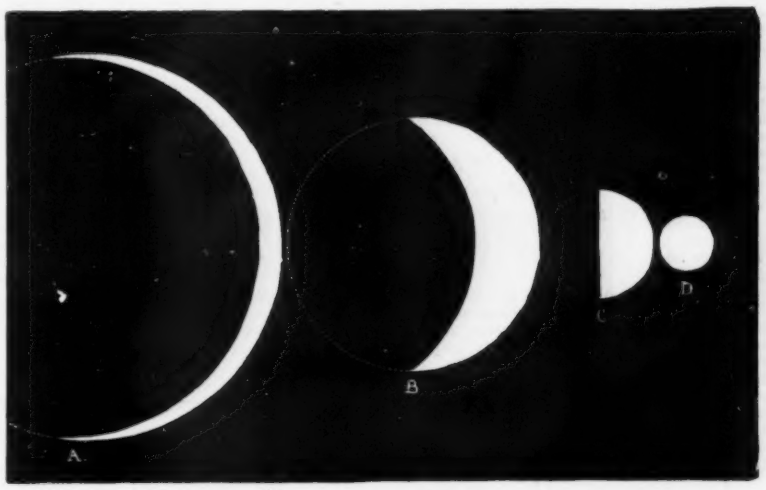
In 1716, the people of London having regarded the visibility of Venus in broad daylight as a prodigy, Halley seized it as an occasion to calculate in which of her positions the planet may be most easily perceived. In 1750, the appearance of the planet at midday also astonished all Paris. This brilliant planet is certainly the one that has been most observed in former times; first, on account of her brightness, and second, on account of her movement. When she disengages herself, in the evening, from the rays of the setting sun, she departs from him a little more every night, increasing in brilliancy, until to a certain distance towards the east, appearing, like the moon, to direct herself towards the left of the observer. At the end of a few months she has removed herself from the star of day to an angular distance that may amount to as much as 48 degrees. In this case, the planet sets more than three hours after the sun.

Brilliant diamond, sparkling in the celestial vault, she predominates over all the other beauties of the heavens; and, for this reason, she has been, in all ages and among all people, saluted by the title, *par excellence*, of evening star. She is the only planet of which Homer has spoken, being designated by him as Kallistos—the "Beautiful." Indeed, does she not appear to be the most beautiful of stars? She was admired as the type of beauty, and her worship reigns supreme in all mythologies. On warm evenings of spring, when the perfumed atmosphere diffuses its caressing breath over the silent fields, how many times has not the "Shepherd's Star" denoted by her rising the long-expected hour of "intimate confidences!" How many times has she not received the vows of lovers, swearing on the eternal heavens and earth a fidelity whose fires were extinguished still more quickly than those of Venus which was insensibly disappearing behind the sun!

After shining for some months, the beautiful planet again, little by little, begins to return towards the sun, becoming more distant from us, and then passes behind him, thus ceasing to be the evening star. Some time afterwards a new star is seen to precede the rising of the sun, advancing by imperceptible degrees every day, and eclipsing likewise all the beauties of the heavens by its dazzling light. It proceeds towards the West, that is, towards the right of the observer. It is Venus again, now become the *Morning Star*. Before recognizing that there were two successive appearances of the same planet revolving around the sun, the ancients believed that they were two distinct stars; the first they called Vesper, star of the evening, and the second Lucifer, the bringer of light.

Soon, after having shone with a most brilliant luster, towards her greatest eastern elongation from the sun, and after having preceded the rising of the latter by three hours, Venus resumes her course anew towards the sun and is lost in the splendor of his light. She is passing then between the sun and the earth, and is at her greatest proximity to us. This is called her inferior conjunction. Sometimes, even, she passes just in front of the sun, as she did in 1874, and will again in 1882. This is called a transit, and can happen but twice in a century.

The length of a complete oscillation with respect to the sun, that is to say, the time that the planet, as seen from the earth, takes to return to the same relative position to the sun, is five hundred and eighty-four days, or one year three months and twenty-nine days. This length of time is naturally the result of the combination of the movements of Venus and the earth around the sun. The two planets effect their revolution in the same direction, the earth in 365 days and Venus in 224.



THE FOUR PRINCIPAL PHASES OF VENUS.

In revolving thus around the sun, the globe of Venus exhibits phases analogous to those of the moon, and variations of size corresponding to her enormous variations of distance. This will be easily seen by referring to the accompanying figure, where her four principal phases are represented. When she is proceeding at her greatest proximity to the earth she exhibits an exceedingly narrow crescent, since she is then between us and the sun, and presents to us only her dark hemisphere. In this position her apparent dimensions are greatest, and she then measures 62 seconds diameter, which is represented in the figure at A by a diameter of 62 millimeters. She is then almost wholly against the sun, and before long disappears in his rays. Sometimes, as we have before said, she passes just between the sun and us, and appears yet a little larger (63 to 64 seconds), but she is then an absolutely black disk, and is no longer a star, properly speaking. In measure, as she departs from us in her movement around the sun, she diminishes in apparent size, while her crescent increases in width. The epoch at which the star appears most luminous is the one that we have represented at the second phase (Fig. B). Then Venus shines at a distance of 39 degrees from the sun, either to the east or to the west, 69 days before or after her inferior conjunction. Her apparent diameter is then 40 seconds, and the breadth of her enlightened position is scarcely 10 seconds. In this position, only a quarter of the illumined disk is seen. This quarter sends us more light than do the more complete phases, because the planet becomes rounded only in measure as she departs from us and appears smaller and smaller. When she arrives at quadrature, at her mean distance from the earth, she is seen as a half moon (Fig. C) of 17 seconds diameter. And when, finally, she has revolved to the other side of the sun and has reached her greatest distance, in her position called superior conjunction, we can see her wholly illuminated disk, but it has a diameter of only 9 seconds and a half (Fig. D).

The phases of Venus were seen for the first time by Galileo, towards the end of September, in 1610. He would have been able to discover them more than a year before, had he directed towards this planet the telescope that he had just constructed. But his observation did not appear to him to be at that moment sure and incontrovertible. In order to give himself time to verify this discovery, without running the risk of having it snatched away from him, the illustrious observer hid it under this anagram:

Hæc immatura a me jam frustra leguntur, o. y.

"These things, immature, and hidden yet from others, are read by me."

By placing the 34 letters of the Latin phrase in another order, these very categorical words are formed:

Cinthiæ figuras emulatur mater amorum:

"The mother of the loves follows the phases of Diana"—an explicit phrase which no longer retains the vagueness of the first, but which clearly affirms the existence of these phases. But who would have been able to turn the first enigma in this manner to get at its true meaning?

Galileo was a man of remarkable acuteness. We find in the collection of Venturi, a letter from Father Castelli to the celebrated philosopher of Florence, dated November 5th, 1610, and in which the former savant asks Galileo whether Venus and Mars might not exhibit phases. Galileo answered that "there were many researches to be made in the heavens, but that, seeing the very bad state of his health, he found himself much better off in his bed than out in the evening dew."

It was on the 30th of December, 1610, only that he announced that he had lifted the veil from Venus. This discovery of the phases of Venus, which exhibit in their general appearance exactly the same particularities as Mercury and Mars, disposed of one of the first objections that had been raised against the Copernican system.

Tradition attributes to the astronomer of Thorn these prophetic words:

"Phases exist and would be visible if we could succeed in seeing clearly the contour of the image." Let us remark, however, that these words are not recorded in the "Treatise on Celestial Revolutions." There, the celebrated author removes the difficulty that had been imposed on him, by saying that the matter of Venus might be self-luminous, or might allow itself to be penetrated and soaked, so to speak, with solar light, to such a point that each of its exterior constituent parts would send back a portion of it earthward.

Persons with excellent sight have perceived these phases with the naked eye. In 1868 especially (the planet being then in its best condition for observation), I received several accounts in regard to this. The fact, although exceedingly rare, is certain; and is so much the more worthy of attention, since, previous to Galileo's discovery, no one had suspected these phases, the absence of which from the Copernican system had been a cause of reproach to the latter. It is possible that they may have been perceived, but that owing to ignorance concerning their real existence, the figure observed may have been attributed to some optical illusion. It is incontestable, in fact, that it is much easier to see a thing that we know to exist, or to which the attention is specially called, than to see the same object under ordinary and indifferent circumstances. Thus, for example, since the discovery of the satellites of Mars a large number of observers have succeeded in distinguishing them in instruments with which they had often observed Mars without suspecting their existence.

The phases of Venus, to beginners in the study of astronomy, present a very special interest. A telescope of medium power is sufficient to recognize them. When they are observed for the first time, it is not rare that the observer experiences a very explainable delusion which makes him believe that it is the moon he sees before him. I have sometimes had much trouble even, in persuading to the contrary certain persons who had thoroughly convinced themselves of it, and nothing less than the absence of the moon from the heavens would have been necessary to prove to them that the star in the field of the telescope could not be our satellite. The best hours for examining Venus through a telescope are those of the daytime. At night the radiation produced by the dazzling light of this beautiful planet prevents the contours of her phases from being clearly distinguished.

The exact measure of the apparent size of Venus, combined with its distance, shows that this planet is almost of the same magnitude as the one we inhabit. If we represent the diameter of the earth by 1,000, that of Venus will be represented by 954. She is, as may be seen, a little bit smaller. Expressed in miles, her diameter is 7,800; her circumference consequently measures 23,400 miles. Her volume is equal to 87 hundredths of that of the earth; her surface exceeds 90 hundredths—that is, it is almost equal to that of our planet. No other globe of the solar republic could offer such a similitude with our own.

Calculations agree in proving that this planet weighs less than ours. Representing the mass of the earth by 1,000, that of Venus would be 787. A knowledge of its volume allows us to calculate therefrom the mean density of the materials that compose it; it is a little less than that of our globe—nine-tenths about. Finally, the weight of bodies is likewise a little less on this planet than on our own; for, designating the force of attraction at the surface of the earth by 1,000, the same force on Venus would be represented by the figure 864. The inhabitants of Venus are a little lighter than we.

By an attentive examination of the irregularities visible along the interior line (or terminator) of the crescent, it has been ascertained that this globe rotates on her axis in 23

hours 21 minutes and 24 seconds. The days and nights there are then only a little shorter than they are here.

The year of the inhabitants of Venus consists of only 231 days. It is divided, like ours, into four seasons, much more marked than ours, and each of which lasts only 58 days.

This neighboring world rotates on an axis still more inclined than that of the earth, causing a greater severity in the seasons. The inclination of the earth is 23 degrees, that of Venus 55. The poet Milton asserts that "the inclination of the axis of our planet was produced, after Adam's sin, by angels coming in the name of divine wrath to chastise the disobedience of our first parents. God being absolutely just, the chastisement must have been proportionate to the sin. We must imagine, then, that on the world of Venus the first human couple committed a much graver sin; and that on this celestial world, neighboring to our own, the first man and the first woman were away beyond the limits of pardon; for the axis of their world has been upturned at an angle more than double that of the patrimony of Adam and Eve. The result is that this world is far from being calm and tranquil, for it passes by turns through the extremes of heat and cold, through all the alternations of the most inordinate passion.

The inclination of the world of Venus being more than twice that of our own, we have only to take a terrestrial globe and incline it that much to learn for ourselves the climate and seasons that result therefrom. It is easily seen that the torrid zone extends, in this case, as far as the frigid zone, and even beyond; and that, reciprocally, the frigid zone extends as far as the torrid zone, and even encroaches upon it, so that there is no place for a temperate zone. There is, then, on Venus, no temperate climate, but all its latitudes are at once tropical and arctic.

Now we know that, beneath the tropics, the sun casts his rays twice a year perpendicularly from overhead, while that in the arctic regions there are days when the luminary does not rise at all, and days, too, when he does not set.

Through what vicissitudes, then, must countries pass which are by turns arctic and tropical? At a certain time of the year the sun does not rise for one or several days; at another time there are one or several days that he does not set, and between these two seasons he rises vertically overhead. The contrast between the frigid temperature of the season deprived of the sun, and that in which the sun of Venus, twice larger and hotter than ours, pours down from the heavens his burning heat on the soil, certainly does not form a very agreeable prospect. Truly, we do not know which is the less disagreeable region of Venus to live in; there would be scarcely any more advantage gained in selecting a residence toward the equator than toward the poles.

From all these circumstances there result, then, climates and seasons that are severer and more varied than ours. The agitation of the winds, storms, and rains must surpass everything of the kind that we see and experience here. The seasons of this planet do not resemble those of the earth and Mars; its atmosphere and its seas undergo a continual evaporation and a continual precipitation of pouring rains, and its heavens are covered with clouds that only rarely allow the geographical soil of the planet to be perceived from here. Judging of it by our impressions, it is certain that we would have less pleasure in that country than in our own; and it is even very probable that our physical organization, as elastic and yielding as it is, could not be acclimated to like variations of temperature. But it ought not to be concluded from that that this world is uninhabitable and uninhabited. It may be even supposed, without exaggeration, that the inhabitants of Venus, organized for living in their medium, are as much at their ease there as fish are in water, and that they judge that our earth is too monotonous and too cold to be inhabited by active and intelligent beings.

If there were no communication between the different regions of our globe the natives of all the countries of the earth would be at no loss for arguments to make them suppose that their own native land was the best in the world, and that it would be almost impossible to live in other countries. For example, if we did not know that the torrid zone was inhabited, and were we unable to visit it, and yet knew by calculation how fearful the heat was there, and how great were the variations of temperature, and to what an extent this zone was often devastated by cyclones, hurricanes, and tempests, we would have very great trouble in believing that any life—either animal or vegetable—could exist and develop there. The same reasoning would apply, by a contrary process, to the polar, boreal, and austral regions, which are, during several weeks, and even months, entirely deprived of solar rays, and undergo in the course of the summer a degree of cold more glacial than that of our severest winters. With such ideas in our mind, we would assuredly be much surprised to learn that the inhabitants of Peru and Columbia on the one hand, and the Lapps and Samoyeds on the other, do very well at home, and even refuse to leave their own countries to come and dwell in ours.

Let us add that, from measures made on the irregularities of the line bordering the crescent of Venus, the existence of very high mountains has been ascertained. The summits of these mountains are illumined at sunrise before the plain which spreads out at their feet, and the contrary takes place at sunset. This is what renders so remarkable the telescopic view of the lunar landscapes along the meridians situated at the limit of solar illumination. In the vicinity of the first quarter, especially, the interior edge of the moon is fringed with sharp and deep hollows, caused by irregularities of the ground, and which produce admirably the effect of lacework, when the magnification employed in observing them is not sufficiently great to reveal their true nature. In reality, one of the most beautiful spectacles in practical astronomy, and at the same time one of the easiest to obtain, is, without doubt, that seen when we direct a telescope toward the silvery star of night during the beautiful evenings that precede the first quarter, and when the astonished eye sees detached from the heavens a crescent of liquid silver, the contemplation of which lifts our thoughts much above the ordinary things of terrestrial life. Now, in measuring the distance that separates the summit of a lunar peak thus illumined from the limits of the shadow, it has been possible to calculate the exact height of all the mountains of the moon.

Analogous phenomena are exhibited by the planet Venus; only her great distance renders them difficult of observation, and, while we have been able to measure the heights of all the mountains of the moon within a few feet, we have as yet been able to distinguish only the high table-lands that stand out from the surface of Venus, as the Himalayas, the Andes, and the Alps do on the earth, but in more considerable proportions. Measures made on these irregularities agree in proving that this neighboring world, although of the same dimensions as ours, possesses mountains that are much more elevated, and the most colossal of which reach a height of 145,000 feet above the lowest level of the land.

Although Venus receives from the sun twice more heat than we, these mountain summits and the high table-lands of her geography may be endowed with a temperature lower than the mean temperature of the inhabited regions of the terrestrial globe. The temperature of a world does not depend solely on its distance from the sun and the quantity of heat received from it, but it depends especially on the state of the atmosphere. In fact, if the temperature be very agreeable at Chamounix and in the valleys of Switzerland, it is not the same at the summits of Mont Blanc and the Alps, that are crowned with eternal snows. And yet all these points are at the same distance from the sun, and receive the same quantity of heat. A very dense atmosphere, saturated with watery vapor, condenses the solar rays and accumulates them at the surface of the earth as in a greenhouse. On the contrary, a very rare and very dry atmosphere allows all these rays to escape and be lost without the soil having received any benefit from them. Measures made of the atmosphere of Venus demonstrate not only that this atmosphere exists, but also that it is more elevated and denser than that which we breathe. The dazzling whiteness of the light reflected by Venus leads us to think, moreover, that this atmosphere is highly charged with clouds. It is probable, then, that this protecting layer tempers the rigor of the two opposite seasons. As we have remarked above, the situation of Venus with respect to the earth is not convenient for a study of her geography, and we are far from having been able to obtain, on this point, the documents that enabled us to begin the geographical map of Mars. It appears probable, however, that the seas extend principally over the equatorial region.

One more and final question:

How do we appear from up there?

It is certainly not disagreeable to us to remark, in conclusion, that, seen from Venus, the earth is a star of the first magnitude, very luminous, and shining at midnight in the midst of the constellations. While our anxious thought seeks to lift one corner of the veil, while our ardent souls fly off toward the upper horizons of creation, and ask how those beings that inhabit Venus are organized, how our neighbors across the way think, how we appear to them from their part of the heavens—no doubt there are at this hour pensive souls up there who ask precisely on their side what beings inhabit our planet and chat with each other (as we are doing now at this moment), asking whether our corporeal organization resembles theirs, whether we enjoy the faculty of thought, whether we are acquainted with astronomy, and whether we see them also from our part of the heavens. So there live, at the same time as we, in the universe, human races, sisters of our own, borne along like us in the vortex of universal and eternal life.

CAMILLE FLAMMARION.

[Continued from SUPPLEMENT No. 175, page 2784.]

ON THE MINUTE MEASUREMENTS OF MODERN SCIENCE.

By ALFRED M. MAYER.

ARTICLE XIX.—(CONTINUED.)

On the Measurements of the Lengths and the Waves of Light; preceded by short accounts of the Undulatory Theory of Light and of the Phenomena of Diffraction and Interference of Light.

We are now in possession of all the information necessary to proceed to the measure of a wave length; in other words, to find out some means of measuring the C *a*, Fig. 78, included between the perpendicular, D *a*, and the edge, C, of the slit, C D. The distance, *r s*, was found to be 15-100ths of an inch, while C D was 15-1,000ths of an inch, and *m s* was 93 inches. With these numbers the above proportion becomes

$$m\,s : r\,s :: \text{C D} : \text{C}\,a = 93 : \cdot 15 :: \cdot 015 : \cdot 0000242,$$

which gives ·0000242, or 242-10,000,000ths of an inch, for the length of a wave of light, which causes in the eye the sensation of red.

Those who understand trigonometry know that the distance, C *a*, Fig. 78, or the wave length, is equal to the length, C D (the width of the slit), multiplied by the sine of the angle, C D *a*; but this angle, C D *a*, is equal to the angle, *r m s*, by reason of the triangles, C D *a* and *r m s*, being similar. The angle, *r m s*, we will soon see, can be very readily and accurately measured by means of a divided circle and telescope. Then with the measure of this angle we obtain the wave length, C *a*, by multiplying C D by the sine of

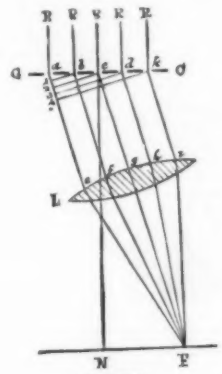


Fig. 83.

the angle, *r m s*; or, calling the wave length, *l*, we have the formula—

$$l = \text{C D} \times \text{sine}, r\,m\,s.$$

Causing light which has come through old red glass to fall upon a slit which was 1·353 millimeter wide, it was found that the angle, *r m s*, was 1° 38'. The sine of 1° 38' equals ·000475, which, multiplied by 1·353 millimeter, the width of the slit, gives ·000642, or 642-1,000,000ths of a millimeter, for the length of the waves of this red light.

The length of a wave of violet light was in like manner found to be ·0000146 of an inch; while green light was found by similar measures and computations to be composed of waves of ether ·0000195, say ·00002, or 1-50,000th of an inch long. These waves of green light are of about the average length of the light waves, which we may therefore remember as being about 1-50,000th of an inch in length. More accurate measures of wave lengths, made by more refined methods, will be given further on. The above measures by the process described are given by way of illustration.

Since light travels as the rate of 185,000 miles in a second, it follows a ray of light of that length (185,000 miles) enters the eye in one second. Hence there are as many tremors or vibrations produced in the retina of the eye in one second as 1-50,000th of an inch is contained in 185,000 miles. Making the calculation, you will find that 586,000,000,000,000, or

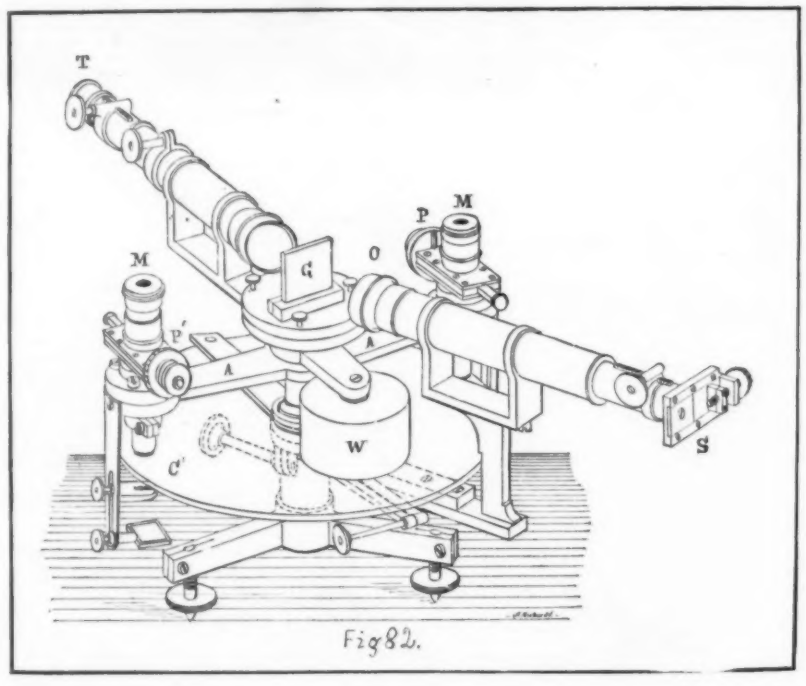


Fig 82.

586 millions of millions of vibrations act on the retina in one second of time!

The method which we have just described for measuring the lengths of the waves of light is not very accurate, by reason of the impossibility of making an accurate measure of the angle, *r m s*, Fig. 78, because of the difficulty of ascertaining the exact center of the dark bands of the diffraction spectrum formed by light traversing a single slit. Therefore, instead of passing the light through a single slit, it is passed through many very fine contiguous slits, or apertures, made by ruling with a diamond several thousand fine lines to the inch on a plate of glass. If we hold before the eye such a ruled plate (known as *a diffraction grating*), with its lines vertical, and look through it at a distant illuminated vertical slit, we shall see the slit just as if the grating were not in

front of the eye, but we will observe, besides this, a series of spectra arranged to the right and to the left of the slit, with their violet ends turned towards it. These spectra have been named, in order of their removal from the slit, as the spectrum of the first order on the right or left, spectrum of the second, third, fourth, etc., order on the right or left. These spectra are of great beauty, the spectral colors appearing in all their purity, and crossed at right angles to their length by hundreds of dark lines called the Fraunhofer lines.

The best way to observe these beautiful phenomena is to place the grating on an instrument known as a spectrometer (Fig. 82), and to look at the spectra through a telescope directed towards the grating. The grating shown at G is placed in front of a telescope, T, known as a collimating telescope, which is formed of an object glass at O, with a slit at E placed at a distance from the object glass equal to the length of its principal focus. In consequence of this arrangement the rays of light which have passed through the slit, S, issue from the objective, O, in parallel lines; so that when we adjust the focus of the telescope, T, to a distant object, and then look through it into the object glass of the collimator, we will see the slit distinctly in focus in the telescope, T. The collimator, S O, is stationary, but the telescope, T, rotates around a vertical axis, and thus can be brought to view the spectrum of any order to the right or to the left of the image of the slit. Opposite to the telescope, T, is an arm carrying a weight, W, which counterpoises the weight of the telescope, and brings its weight and that of W directly downward in the direction of the central axis around which the telescope revolves. The telescope in its motion carries two arms, A and A′, to whose extremities are attached the two micrometer-microscopes, M and M′. These microscopes in their motion run over the graduations on the border of a glass circle, C, and thus give the angular distances of any point of a spectrum from the center of the image of the slit. These divisions on the circle are cut with a fine diamond, and are illuminated by mirrors placed under the glass circle. One of these mirrors is shown at R. This drawing is from the instrument designed and constructed by Mr. Lewis M. Rutherfurd, of New York, who is the first person, I believe, to construct an angle-measuring instrument with its graduated circle of glass. The advantages of a glass circle are: First. That the lines of the graduation may be of any desired fineness. Secondly. Facility of illuminating these lines by reflecting light to them through the glass circle, and thus permitting them to be examined by microscopes magnifying several hundred diameters. Thirdly. Smallness of dimensions of the circle, combined with great accuracy in the readings. Fourthly. Cheapness. Fifthly. Avoidance of flexure and effects of unequal heating of the circle.

The circle, C, is ten inches in diameter, and is divided into 10 minutes of arc by Mr. Stackpole, of New York. The diamond point with which these divisions were cut was so excellent that the lines are of the greatest delicacy, being much finer, as seen in the microscopes, than the spider lines by means of which bisections are made with the microscopes. The two micrometer-microscopes, M and M′, magnify 75 times, and each whole turn of their screws equals one minute. As the heads, P, P′, of these screws are divided into 60 parts, it follows that one of these parts equals one second of arc. Mr. Rutherfurd has found that the errors of successive bisections of a line on his circle is less than half a second of arc. In a short account which Mr. Rutherfurd has published of his new circle, he says:

"I am convinced, from the ease with which one second is read on my instrument, with microscopes only 4¼ inches long, including objectives and eye-pieces, that upon a circle of 15 inches, provided with powerful microscopes, greater precision could be attained in the reading of angles than with the largest metallic circles now in use.

"For the purpose of showing the degree of precision attainable, I add two series of bisections of lines on the circle made by myself and two made by a lady, marked respectively R. and M.:

R.	R.	M.	M.
7·5″	1·8″	23·6″	11·0″
7·4	1·3	23·6	11·2
7·7	1·9	23·3	11·8
7·4	1·8	23·8	11·0
7·3	1·8	24·5	10·9
7·6	1·8	23·9	11·5
7·7	1·9	23·7	11·5
7·4	2·0	24·0	11·5
7·6	2·3	23·9	11·0
7·8	2·3	24·3	11·4
Mean, 7·54″	1·89″	23·86″	11·28″

"It will be readily seen that the probable error of any single reading in any one of these series is considerably less than half a second, while the probable error of the mean of any series is a much smaller fraction."

With this instrument one can measure in the spectra of the different orders the angular distances from the center of the image of the slit to the various Fraunhofer lines in these spectra; and from these angular measures, together with a knowledge of the exact number of lines on the grating in an inch, we can readily compute the wave-lengths to the last degree of precision, as we shall presently show.

The angular distance from the center of the image of the slit to the same Fraunhofer line in the spectra of the different orders will be nearly in proportion to the number of the order of the spectrum. Thus, if we call a the angular distance of one of the D Fraunhofer lines in the spectrum of the first order from the center of the slit, then this angular distance will be $2a$, $3a$, $4a$, in the spectra of the 2d, 3d, 4th, etc., orders. It follows from this that the length of the spectrum of any order will be as the number of the order; thus the spectrum of the 4th order is four times as long as the spectrum of the 1st order. The length of the spectrum of any given order will be inversely as the distance between the lines of the grating. Thus, a grating of 10,000 lines to the inch will give a spectrum of any given order twice as long as the spectrum of the same order given by a grating having 5,000 lines to the inch.

We will now explain the action of a grating on a beam of light which traverses it, and will show how, with a grating and a spectrometer, the waves of light are measured. In Fig. 83, G G represents a grating having apertures in it at a, b, c, d, k. R, R, R, R, R, are rays of light from the collimator, falling perpendicularly on the plane of the grating. Whenever light falls upon such narrow apertures as those in the grating, each point in these apertures becomes a center of origin of vibrations, and from each of these points rays diverge in all directions on the side of the grating opposite to the incident rays, R, R, R, etc. All the particles of ether situate in the plane of the apertures in the grating have the same phase of vibration, and therefore all those rays which have traversed the grating in the same direction in which they struck it will have the same phase of vibration when brought together in the focus of a lens on a screen, or in the focus of the eye on the retina, and will form on these surfaces a white image of the slit of the collimating telescope. This is not the case, however, with bundles of parallel rays which diverge laterally—say in the direction $a\,e$, $b\,f$ $c\,g$, $d\,h$, etc. If these rays be brought to a focus, F, by the lens, L, we will see at F not a white image of the slit, but a colored one; and the kind of color which is formed at F will depend on the inclination of the diffracted rays to R N, a perpendicular drawn to the plane of the grating. Suppose that the diffracted rays, $a\,e$, $b\,f$, $c\,g$, etc., are so inclined to the plane of the grating that a perpendicular, b 1, let fall from the center of one opening in the grating to the parallel ray, $a\,e$, emanating from the center of the contiguous opening, cuts off on the ray, $a\,e$, a distance, a 1, equal to the length of a wave of violet light of a certain tint. Imagine other perpendiculars, c 2, d 3, etc., let fall in like manner upon the ray, $a\,e$. Now, if all these rays, $a\,e$, $b\,f$, $c\,g$, $d\,h$, etc., be brought to a focus at F, the vibrations of the ether at this focus will all have the same phase, and therefore the lens will produce at F an image of the slit, which will be formed of violet light; and the intensity of this light will equal the sum of the intensities of all the separate parallel rays, $a\,e$, $b\,f$, $c\,g$, etc., which converge to the focus. The same action will take place with any other set of rays parallel to those just described and all starting from symmetrically placed points in the openings. From the above it follows that all rays emanating from the opening and parallel to the rays, $a\,e$, $b\,f$, $c\,g$, etc., and having wave lengths equal to a 1, will act together in their vibratory motions when brought to a focus at F. But it is not so with other rays which, although parallel to the rays $a\,e$, $b\,f$, etc., the length of whose waves does not equal a 1, for they will not have the same phase of vibratory motion when brought to meet at the focus, F. To make this clear, let us consider a series of rays of red light which proceed parallel to $a\,e$, $b\,f$, etc., and come to a focus at F. These rays are formed of waves which are nearly twice as long as those forming violet light; or, in other words, they are nearly twice as long as the distance a 1; hence red rays, which have emanated from symmetrically placed points in two contiguous openings of the grating and proceed in a direction parallel to $a\,e$, will, on meeting at the focus, F, all differ by half of an undulation, and hence red light cannot exist at F with an inclination of diffracted rays equal to N e F, but can only exist at a point at such angular distance from R N that the perpendiculars let fall from $a\,b\,e$ and d on to $a\,e$ cut off on this latter line distances which are respectively equal to double the lengths a 1, a 2, a 3, a 4. If, indeed, the wave lengths of two rays emanating from symmetrically placed points in two contiguous openings and proceeding parallel to $a\,e$, differ by only 1-1,000th of the wave-length of one of these rays, then these rays will also interfere when brought to the focus at F, because the phases of the vibrations of the rays symmetrically placed in the first and second opening of the grating will differ by 1-1,000th of an undulation; similarly, those rays emanating from the 1st and 501st openings will differ by 500-1,000th or half of a wave-length, and therefore will interfere. The same interference will take place between the rays from the 2d opening and those from the 202d, and those from the 4th and 504th openings, and so on. Hence rays of light having any other wave-length than a 1 will almost completely disappear as light by their interference, and the light concentrated at the focus, F, will be that which is produced by ethereal vibrations of wave lengths equal to a 1. The same reasoning holds good for any bundle of parallel rays having diffracted angles different from N e F, and the consequence is that the lens will form a pure spectrum at its focus, F. From the above discussion it is apparent that there is a connection existing between the angle, N e F, of the diffracted rays, the length, a 1, and the color observed at F. The color at F varies with the angle, N e F, or, what is the same, with the length, a 1. In the red rays at the extreme end of the spectrum the angle, N e F, is at its maximum, and a 1 has a length of about ·00077 of a millimeter, for the extreme violet rays at the other end of the spectrum, the angle, N e F, is at its minimum, and a 1 is about ·00039 of a millimeter long.

It is now clear that the determination of a wave-length comes to the measurement of the length, a 1. To measure this length, we first determine the distance between the centers of two contiguous openings in the grating. This we do by measuring the whole breadth of the grating, and dividing this breadth by the number of lines, less one, cut on the grating. We then measure the angle, N e F, corresponding to any given color or Fraunhofer line in the spectrum, by means of the telescope, T, and divided circle C, Fig. 82. Now, since the angle $a\,b$ 1 is equal to the angle N e F, it follows that a 1 is equal to $a\,b$ multiplied by the sine of N e F, which is the same trigonometrical calculation that gave us the length, C a (the wave-length) in Fig. 78. Let s stand for $a\,b$, d for the angle, N e F, and l for a 1, or the wave length; then $l = s \times \sin d$. If the ray, $a\,e$, and symmetrically placed rays, be inclined to the plane of the grating so that the perpendicular, b 1, cuts off on $a\,e$, a distance, a 1 equal to two wave lengths, we shall have the same actions over again, only the spectra produced by them will be more deflected to the side of the image of the slit, and thus are produced the spectra of the 2d, 3d, 4th, etc., orders. The wave length of a certain tint can be determined from angular measures on this tint made in the spectrum of any order; and then if we call n the number of the order of the spectrum, we have the formula $l = \frac{s \times \sin d}{n}$.

In the majority of the measures which have been made to determine wave lengths to form the mass of "the normal solar spectrum," the plane of the grating is placed in the axis of a divided circle, and is adjusted so that the plane of the grating, C, Fig. 82, is at right angles to the line of collimation of the collimating telescope, O, carrying the slit, S. The observing telescope, T, is placed on the other side of the grating, and rotates around the axis of the instrument, while it carries with it the micrometer-microscopes, which run over the graduations on the circle, C, and serve to measure the angle N e F, of Fig. 83.

Mascart, now Professor of Physics in the College de France, made a notable improvement in this process of measuring wave lengths. He placed the plane of the grating not perpendicular to the axis of the collimator, but tilted the plane of the grating to the axis of the collimating telescope till the Fraunhofer line, whose wave lengths he wished to measure, appeared with its least angular deviation from the axis of the collimator. By this method Mascart obtained great simplicity of adjustment, combined with increased accuracy, in his measures. In Mascart's method the formula already given for measuring the waves becomes $l = \frac{2s}{n} \times \sin \frac{d}{2}$. The letters in this formula refer to the same quantities as explained in the previous formula, $l = s \times \sin d$. In Mascart's formula d stands for the angle of minimum deviation just referred to.

Mascart concluded, from his measures of wave lengths, that the upper or more refrangible of the two D-lines of Fraunhofer has a wave length of ·0005988 of a millimeter. This measure is the same as that made by Fraunhofer, and physicists now generally adopt this determination as exact, and use this line as a point of departure in making measures of wave lengths. If the wave length of any one ray is known to the last degree of precision the position of this ray in the spectrum may afterward serve as a point of departure in the determination of other rays by merely observing their angular distances from this standard ray.

If we knew with absolute certainty the length of a definite ray in the spectrum corresponding to one of the lines of Fraunhofer, this length would readily be a natural standard of length, and might be used as such for building up, by its multiples, the standard of length of the world. It would have the advantage over other standards now existing that it could be readily reproduced if lost, and could be readily obtained by men of science in any part of the globe. The manner in which this new standard of length may be obtained is about as follows: Having selected a certain Fraunhofer line in the spectrum, or what would be as well, a bright line produced by the incandescence of a vapor like that of sodium, we proceed to measure its angular deflection from the image of the slit. This we do by measuring the angular distance, separating the position of this line in a spectrum of a certain order on the left from its position in the same order of spectrum situate on the right of the axis of the collimator; the half of this angular measure equals the angular distance of the line from the image of the slit in the collimator.

Now in the formula, $l = s \times \sin d$, we determine l, the wave length, from the measure, s, the distance between two contiguous openings on the grating, and d, the angular distance of the ray (corresponding to l) from the image of the slit of the collimator; but in our determination of the standard the wave length, l, is supposed to have been already measured and known to the last degree of precision, and our problem is an inverse one, viz., to determine s, the distance between the centers of two contiguous openings in a grating whose lines are cut so that they are straight, parallel, and equidistant. This measure, s, is given by the formula, $s = \frac{l}{\sin d}$. Now knowing s, we can determine the width of the whole grating by counting the number of lines on it and multiplying this number less one by the distance, s. The width of the grating is now known, and this measure we use as the length from which our standard is built up.

In the following table we give the wave lengths of the principal Fraunhofer lines of the solar spectrum as determined to the ten-millionth of a millimeter by the observers named at the heads of the columns:

Fraunhofer Lines.	Fraunhofer.	V.d.Willigen.	Ditschleiner.	Angström	Stefan.	Mascart.
A		·0007609		·0007604		
a		·0007189		·0007183		
B	·0006878	·0006871	·0006883	·0006867	·0006873	·0006867
C	·0006564	·0006565	·0006571	·0006562	·0006578	·0006561
D_1		·0005898	·0005905	·0005895		·0005894
D_2	·0005888	·0005896	·0005899	·0005889	·0005893	·0005888
E	·0005265	·0005272	·0005278	·0005269	·0005271	·0005268
b_1		·0005186	·0005192	·0005183		·0005182
b_2		·0005175	·0005181	·0005172		·0005165
F	·0004851	·0004864	·0004868	·0004860	·0004869	·0004860
Hγ		·0004342	·0004346	·0004340		
G	·0004292	·0004311	·0004317	·0004307	·0004291	·0004308
H_1	·0003945	·0003971	·0003974	·0003968	·0003959	·0003967
H_2		·0003938	·0003940	·0003933		

The differences which the reader will detect in the above determinations of the wave length of the same ray of light by different observers are not due entirely to the differences which always exist between real measures of precision, but they are owing principally to the differences existing in the character of the rulings on the diffraction grating used by the several observers, and the uncertainty existing in their determinations of the distances separating the centers of contiguous openings in their gratings.

All investigators in optics, till quite recently, obtained their diffraction gratings of the celebrated mechanician, Nobert. The best gratings known to us are those which have, for several years past, been cut on a ruling-engine devised and constructed by Mr. Lewis M. Rutherfurd, of New York city. By the courtesy of the publishers of the New American Cyclopædia we are permitted to present the readers with a cut and description of this ruling-engine, taken from "Spectrum," an article written by the author.

On a hollow cast-iron block, see Fig. 84, are cut, at right angles to each other, two V shaped guides. On one of these guides slides the iron plate, D, moved by means of a screw acting in a nut attached to its under surface. On this plate is fastened the plane piece of glass or speculum metal which is to be ruled; on the other guide slides the plate, L J, having a reciprocating motion given to it by a lever, the action of which will be described further on. To this plate is attached the tool holder carrying the diamond-pointed cutter. The motive power of the machine is a small turbine, from which passes a cord around the driving wheel. On this driving wheel is a pin to which is jointed the connecting rod, A F. This connecting rod is hollow, and in it moves a rod which is constantly pressed toward the pin on the driving wheel by the spring shown at A. When the rod, A F, moves upward, the arm, F I, oscillates on its rocking shaft (the end of which is seen in the figure, projecting horizontally), until the end, I, of this arm comes against the fixed pin placed under it, and in contact with which it is shown in the drawing. Just before this upward movement of the rod, A F, begins, the pawl, H, falls into a notch on the feed wheel, B, which is attached to the screw of the engine, and during the upward motion of the rod, A F, the pawl, H, presses against the notched wheel and rotates it a definite fraction of an entire revolution. The pawl, H, having completed its "throw," the crank-pin on the driving wheel passes its upper center, and then the slotted lever, G, lifts the pawl out of the teeth of the wheel, B, so that no jarrings or tremors are given to the machine while the pawl is retreating to take fresh hold on the feed-wheel, B. A pin attached to the connecting rod passes through a slot in the tube, A F, and serves to hold the two together when the rod is making its downward motion. The amount of rotation to be given to the feed-wheel, B, is regulated by rotating to the right or to the left the collar on the rock shaft, to which the pawl, H,

is jointed. Directing attention to the plate, L J, to which is attached the cradle, N, carrying the diamond pointed rod, M, we observe, at K, the right hand end of a rod, the extremities of which pass through holes in the iron frame of the engine. This rod is moved parallel to the V guide of the plate, L J, by means of an oscillating lever which works in a vertical slot attached to the rod, K, and is fixed on the same rock-shaft which carries the lever, F I. Projecting upward from the rod, K, is a short rod whose end is shown at L. This rod moves in a short slot cut in the direction of the length of the plate, L J, as shown in the figure. The action of the cutting point of the tool, M, can now be explained. While the pawl, H, is rotating the feed-wheel, C, the rod, L, presses against the left-hand end of its slot and moves the slide, J, from right to left. The plate, J, cannot move as above indicated, until the rod, L, touches the left-hand end of its slot; and when it reaches this position, the left hand end of the rod, K, has moved to the left sufficiently to press against the lower point of the cradle, N, and hold the diamond-pointed tool, M, elevated above the plate of glass or speculum metal during the entire left-hand motion of the plate, J. When the end, F, of the lever, F I, descends, the rod, K, moves from left to right, and the projecting pin has to move up to the right hand end of its slot before it can push the plate, J, to the right. During this motion of L in its slot, the left end of the rod, K, has allowed the diamond point on M to rest on the glass plate, so that before the plate, J, begins its right-hand motion the diamond point is at rest on the plate to be ruled. The plate, J, now moves to the right, and the diamond point cuts a line. But the diamond point is lifted before the right-hand motion of the plate, J, ceases, by the side arm, O, of the cradle, N, coming against the inclined surface of the side piece, P. The diamond is thus raised, and is held in this position by the depression of O against P, until the left-hand end of K has moved up to the cradle and holds the tool elevated during the motion of the plate, J, to the left. After this motion has ceased, the diamond is lowered to the glass plate, and another cut is made; and so on, the machine working automatically until the plate is ruled. The pitch of the screw is 1-48th of an inch; hence, by knowing the fraction of the revolution made by the screw between two successive cuts of the engine, we know the distance, a fraction of 1-48th of an inch, separating the centers of two contiguous lines on the grating. The diameter of the feed wheel, B, is 6 in., and from this dimension the reader may estimate the size of the other parts of the engine. The excellence of the work done by this engine depends on certain peculiarities of construction: 1. The errors in the throw of the screw, caused by its eccentricity, or want of coincidence of the axis of figure of the screw and its axis of motion, are corrected by giving to the feed wheel, B, an eccentricity opposed to that existing in the screw. The screws at C, C, C, C, serve to alter the position of the center of the feed wheel, B, and thus to obtain the required eccentricity. This balance of opposing eccentricities is obtained by a delicate and precise method devised by Mr. Rutherfurd. A grating ruled by the engine on speculum metal is examined at such an angle of reflection that the light reflected from the plate appears of one color, for example, red. If we could cause the lines on this grating gradually to approach each other, and narrow the spaces separating them, we should observe the red tint becoming gradually lighter in hue, and gradually changing into orange, yellow, green, etc. Hence uniformity of tint is an indication of uniformity of ruling; therefore, if we tilt a grating placed in front of a flame and examine it by means of a lens and find it of a uniform color, we are sure that the screw is doing accurate work; but if the screw has a periodic error-like eccentricity, then we shall observe a columnar appearance on the plate, owing to periodic variations in depth of color. By a careful comparison of the positions of these colors with the known positions of the screw when the corresponding portions of the grating were cut, we ascertain the direction in which to move the center of the feed wheel, B, in order to correct the eccentricity of the screw. 2. The nut in which the screw of this engine works is three inches long, the threaded portion of the screw being 3 1-2 inches long. This long nut tends to preserve the accuracy of the engine's work. 3. The original method devised by Mr. Rutherfurd to obtain rectilinear V guides is a new and important feature of this engine. A collimating telescope with a vertical slit, or cross-threads at the focus of its object glass, is placed in a firm position in a line with the guide to be tested. On the slide which moves on the V guide is fastened a telescope with cross-threads at its focus. The slit of the collimating telescope is viewed in the other telescope as the slide carrying the latter is moved to and from the collimator. If the slit is constantly bisected during the motion, the guide is accurate; but if the image of the slit moves when referred to the cross-thread, then the guide has to be corrected until by trial the image of the slit remains stationary during the motion of the telescope. 4. The pawl, H, during its retraction does not fall over the teeth of the feed wheel, and by jarring the machine cause the diamond to cut an irregular or wavy line. 5. The method of lifting the diamond point while it is obtaining its position for a new cut is the simplest we know of. 6. The screw of this engine, on which its work mainly depends, is constructed as follows: A screw is first cut in a lathe with a single pointed tool, then scored; it is then hardened, and thus a tap is obtained. This tap is now centered by its threads, and cylinders are ground on its ends so that they are concentric with the threads of the screw. Blocks of metal are now firmly screwed on the bed-plate of a planer, and V's are cut in these blocks to support the cylindrical end of the screw tap. A stock holding blank dies is placed in the tool holder of the planer, and these dies are screwed against the screw tap. The stock is then firmly screwed to the tool holder. The threads of the dies are now cut by rotating the screw tap two or three times through the dies; then, relieving the die stock in the tool holder, the dies are again tightened on the screw tap; the stock is now screwed tightly on the tool holder, and the screw tap is again traversed through the dies. This operation is repeated till the dies are finished, when they are hardened. A screw which is to serve for the ruling-engine is now cut on the lathe with the same single-pointed tool which cut the thread of the master tap. This screw is nearly finished on the lathe. It is then placed in the same V's which previously held the master tap, and the dies just described are placed in the tool holder of the planer, and with them the thread of the screw is finished. The screw is now rotated on its threads in a long cast iron V, and shoulders are turned down on the ends of the shaft of the screw. The nut for this screw is cut with a single-pointed tool. The screw is now run into its nut, and they are ground together with powdered pumice stone. The screw of this engine has only one collar, on which it turns near the feed-wheel, B. The other support of the screw is the long nut. Without this arrangement, Mr. Rutherfurd found it impossible to cut regular gratings.

A NEW THEORY OF TERRESTRIAL MAGNETISM.

By Profs. PERRY and AYRTON.

AT a recent meeting of the Physical Society, London, Mr. Ayrton explained, on behalf of Prof. Perry and himself, a theory of terrestrial magnetism which has the great novelty that it makes the existence of the earth's magnetism depend solely on the earth's daily rotation, and does not require, as do all other theories based on electro-magnetic phenomena, the existence of other bodies in the universe. In fact, they have arrived at the result that if any body of any material has a static electric charge, and if it rotates about an axis, then *per se* there will be a magnetic field in the interior of this body as well as in the neighborhood outside.

In 1876, Mr. Rowland, working in Professor Helmholtz's laboratory, proved experimentally that a quantity of electricity in mechanical motion acted like an electric current in deflecting a magnet, and it is on this result that Profs. Perry and Ayrton have based their whole theory. For they point out that since the points near the surface of the earth have different linear velocities from those in the interior (although all the points have the same angular velocity of rotation round the earth's axis), it follows that if the earth had an initial electrical charge, residing of course in accordance with the well known electrical law on its surface, the electrified particles would have velocities relative to the remainder; hence, as a direct consequence of the results of the experiments published by Professor Helmholtz, the interior of the earth would be a magnetic field, quite independently of its interior constitution, and precisely similar reasoning, of course, proves that outside the earth's surface there would also be a magnetic field.

In order to solve the difficult problem of determining the electro-magnetic potential at any place, they have calculated the magnetic forces produced at any point, first by the rotation of a small electrified area on the surface of the earth, and then, by summation, the force produced by the rotation of the whole electrified surface; and they have shown that these forces are the same as would be produced by certain definite distributions of attracting matter over the earth's surface, from which, by the use of spherical harmonics, they have arrived at the conclusion that if the earth had an angular velocity of rotation around its axis, ω, and a uniform electric density, σ, then there must be an electro-magnetic potential at any point inside the earth equal to—

$$\frac{4\pi}{3} 2\sigma\omega r \cos\theta,$$

and at any point outside the earth—

$$\frac{4\pi}{3} \sigma\omega \frac{1}{r^2} \cos\theta,$$

where the unit of length is the earth's radius, r, the distance from the earth's center of the place in question, and θ its co-latitude.

Now this electro-magnetic potential will be accompanied with certain magnetic forces varying from point to point, and the magnitude of these forces will depend on the interior constitution of the earth. As an example of their conclusion, they examine what would be the distribution of magnetic intensity if the earth consisted of a hollow iron shell, and they have, using Poisson's formula, arrived at the following result: If such an iron shell has an initial uniform charge of static electricity, and if it has an angular velocity of rotation round a diameter, then, independently of all other bodies in the universe, and independently of the co-efficient of magnetization of the iron, there will be at any point on the surface of the sphere, having a latitude, λ, a magnetic force proportional to—

$$\sqrt{1+3\sin^2\lambda}$$

But this result is the same as that given by Biot's well-known law for the distribution of magnetic intensity on the earth's surface, hence giving considerable probability to their theory.

It is important to notice that in previous examinations of the earth's magnetism it has been usual to start with the known law of distribution of magnetic intensity, and then deduce what arrangement of magnets, etc., inside the earth would lead to this distribution; but in this new theory of Profs. Perry and Ayrton they start merely with an experiment described by Prof. Helmholtz, of the effects of a rotating electrified body, and show from this that the earth by its rotation alone *must* be magnetic, and next prove that if there be an iron shell, thick or thin, in the earth, then the distribution of magnetic intensity on the earth's surface will be the same as is known to exist from observation.

Next as regards the sign of the electric charge on the earth's surface required to produce the earth's magnetic polarity. Is it in accordance with the known phenomena of atmospheric electricity? To produce the earth's magnetism we must have, in accordance with the known laws of electro-magnetism, a *negative* current flowing from west to east, or in the direction of rotation of the earth. In the language of the new theory, therefore, the surface of the earth must be *negatively* charged, but Sir William Thomson has proved, by observations with his electrometer, that all the phenomena brought to light by atmospheric electricity, on a fine day, would be observed just as they are if the earth had a *negative* charge.

Lastly, in order to get a rough approximation of what sum be the difference of electric potential between inter-planetary space and the earth, so that its own electric charge alone combined with its known rate of rotation round its axis shall produce the earth's magnetic moment, as determined by Gauss, Profs. Perry and Ayrton take as an example a solid sphere of iron of the size of the earth, and rotating with the earth's known rate of rotation, and they prove mathematically that something like a difference of potential a hundred million times the electromotive force of a single Daniell's cell would be sufficient for this purpose. They notice that there is no difficulty in imagining such a difference of potential to exist between the earth and inter-planetary space, seeing that there exists between the earth and the planets an enormous region of space having an insulation far higher than that of such a vacuum as experiment has shown will not allow the passage, from one point to another very near it, of a spark produced by a large induction coil.

Lastly, they draw attention to the fact that they have assumed the distribution of the electric charge on the earth's surface to be uniform, and so have arrived at a distribution of magnetic intensity dependent only on the latitude of the place, but that since it is possible that the sun and planets may have potentials differing immensely from that of the earth, it might be expected that the distribution of electric charge on the earth's surface, and consequently the magnetic intensity, would have variations like those of the tides, in fact such variations as are known to exist; also, that it would be anticipated that any sudden formation of vapor on the earth's surface, or alteration of the sun's atmosphere, or anything causing change in the lines of *static electric induction* from the sun to the earth, ought to cause disturbances such as we know as magnetic storms. The alignments of planets with the sun and earth, again, or the proximity of planets to the sun having less than the average difference of electric potential from it, ought to diminish the disturbances in the solar envelope and produce the alteration of sun spots and terrestrial magnetism which is known to accompany such planetary motions. And, lastly, the authors point out that the known lagging of changes in terrestrial magnetism behind variations in the sun spots would be explained if the great pressure to which the iron in the earth's interior is subjected produces, as is very probable, considerable coercitive force, for such coercitive force would necessarily cause changes in the magnetic intensity to lag behind the disturbances in the earth's electric charge produced by alterations in the static induction of the sun and planets.

SEBERT'S PROJECTILE VELOCIMETER.

THE instrument illustrated by the accompanying engravings has been constructed by Mr. Sebert, and serves to measure the velocity of projectiles thrown by firearms, as well as the pressure exerted on the bottom of the same and the distance traversed during the recoil or "kick."

Various instruments have been devised already for this purpose, but all of them lacked that degree of precision and rapidity of operation necessary for obtaining reliable results. The apparatus of Mr. Sebert is quite novel in its construction, with the exception of the automatic electric registers, which are identical with those used heretofore for similar purposes by Mr. Marcel Deprez.

In Fig. 1 of the accompanying engravings, A is a wooden support inserted in the ground, carrying a cross-piece, B, on

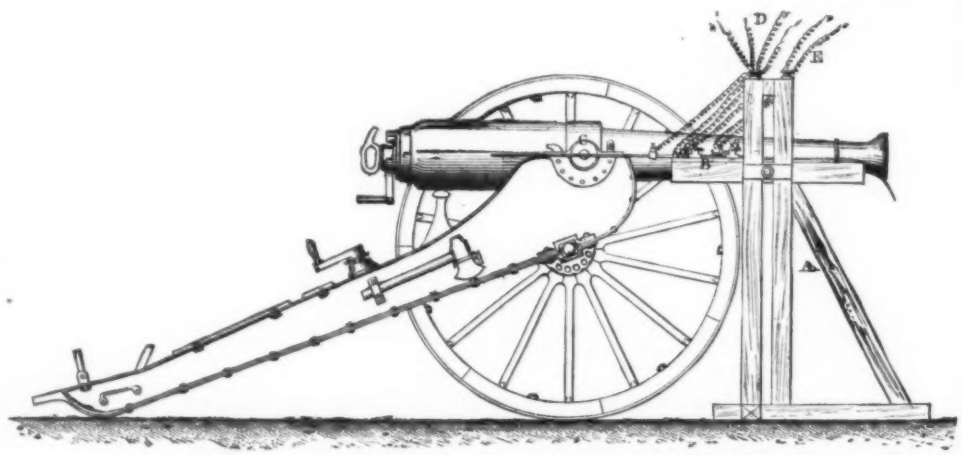


FIG. 1.—SEBERT'S PROJECTILE VELOCIMETER

which is firmly fastened the instrument proper, of which Fig. 2 is a front elevation and Fig. 3 a plan view. The uprights forming part of the support, A, are provided at the top with sockets, receiving the wires connecting the instrument with a battery, and held in position by screws. The instrument proper consists of a plate, C (Figs. 2 and 3), on which are fastened two guide rails, B B, between which slides freely an elastic steel band, A. This is attached by means of a clamp, d, to a stout wire connected at its other extremity by another clamp, d', with the cannon. The steel band is covered on its upper surface with a thin coat of lampblack, into which the results of the experiment are recorded. Directly above the band is placed a diapason, or vibrating fork, E, kept in constant regular motion by an electric current, interrupted regularly in extremely short intervals. One of the teeth of the fork carries a very fine pencil, recording the oscillations of the fork on the blackened surface of the band. As long as the latter is not moved, the vibrations of the fork will only produce a fine transverse line, but as soon as it is drawn along by the motion of the cannon or some other force, the point of the pencil will describe an undulated line, the length of the undulations of which corresponds to the distance traversed by the cannon during the respective oscillations of the fork. The undulations of the line are naturally very small, and in observing them a micrometer is employed.

The duration of the passage of the projectile through the barrel, as well as the velocity of the projectile at different moments after leaving the mouth of the cannon, may be de-

termined by means of interrupters placed at the mouth of the gun and at the respective distances from the same, actuated by the projectile when passing, and connected by wires with a corresponding number of automatic Deprez registers, G. These are composed of small electro-magnets, the armatures of which end in fine points, which, as soon as the current is interrupted, produce a mark on the surface of the steel band, the position of which indicates the time consumed up to the moment of interruption.

Notwithstanding the accuracy and promptness of action characterizing these electric registers, a certain loss of time arises, nevertheless, from the resistance offered to the current and the friction encountered by the movable parts; on account of the minuteness of the periods in question, even the smallest incorrectness must be taken into consideration,

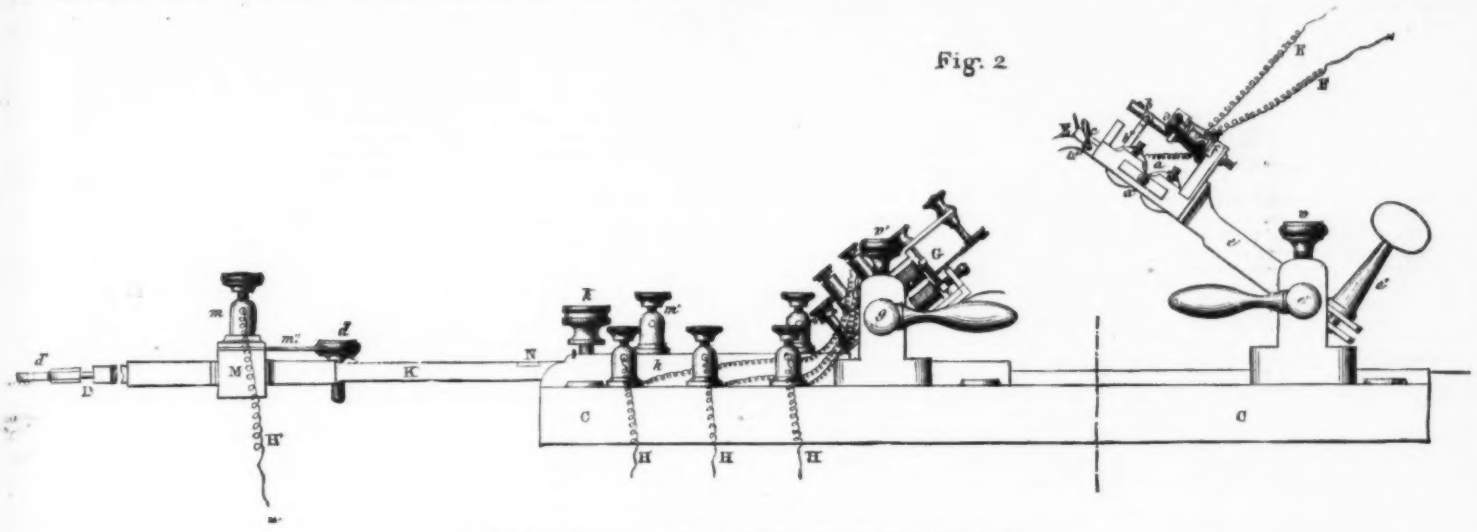


Fig. 2

SEBERT'S PROJECTILE VELOCIMETER.

and for the purpose of determining the error, an attachment is provided, constructed as follows:

To the plate, C, is fastened, by means of screws, a rectangular case, K′, into which is inserted a movable steel bar, K, held in position by a screw, R. Into the bar, K is, at N, inserted an isolating ivory tablet. On the bar slides a crosspiece, M, connected with the clamp, *d*, by means of which the steel band, A, is fastened to the wire, D. To the crosspiece, M, a curved spring, *m*″, is attached, the extremity of which rests on the bar, K. This mechanism is made to form part of the circuit by means of wires attached by screws at *k*′ and *m* respectively. The point of the spring, *m*″, being placed precisely at the edge of the ivory tablet, the current is interrupted, and the points of the registers, G, record a mark on the surface of the band, A. When afterwards the experiment is actually made, the length of the mark made while the point of the spring, *m*″, passes over the ivory tablet, does not correspond with the length of the latter, and the difference indicates the time lost by the transmission of the current and the friction.

The tongue, E, makes 2,000 vibrations per second, and can indicate as many as fifty interruptions of the current during that time.

Experiments made with a cannon of 9·36″ bore gave the following results, three Deprez registers being used:

Duration of the passage of the projectile from the bottom to the mouth of the gun, 0·01124 second; time consumed in reaching an interrupter placed at a distance of 108·24′, 0·07305 second; time consumed in reaching an interrupter placed at a distance of 272·24′, 0·1127 second.

From these numbers the velocity of the projectile, when at a distance of 52·48 and at 252·72′, may be calculated, and will be found to be 1469·94 and 1453·696′ per second respectively.

The area of the bottom of the cannon, the weight of the projectile and gun, and the distance traversed by the latter being known, the pressure exerted by the charge may be easily calculated.

The experiments so far made show that after the projectile has left the gun, the backward motion of the latter increases yet in velocity, owing to the expansion of the gases yet remaining in the barrel.

The same instrument may also be used for determining the velocity of the pistons of steam, gas, and atmospheric engines, of drop-hammers, etc., only slight alterations being necessary.—*Bulletin de la Societe d'Encouragement.*

[Continued from SUPPLEMENT No. 176, page 2796.]

USE OF COMPRESSED AIR MOTORS FOR STREET CARS.

WHAT GRADES CAN THE PNEUMATIC MOTOR OVERCOME, AND WHAT LOAD CAN IT CARRY?

These are pertinent questions, and can be readily answered.

Ordinary locomotives are so proportioned in their boiler and cylinder capacity as to be able to slip their wheels on a dry rail if the engine should be chained fast, so that it could not advance upon the track.

In that case the adhesion which is, at a maximum, about one-fifth of the weight upon the drivers, measures the power of the engine and not the pressure in the cylinders. The power varies, and is greatly reduced in bad conditions of the track.

Power of Motor Cylinders.—Assumed that the air is used under 16 atmospheres, cut off at one-sixteenth and expanded to fill a cylinder at atmospheric tension, giving mean pressure 0·236. The initial pressure being 16 atmospheres, the mean pressure is 16×·236=3·776 atmospheres, and 3·776×15=56·64 pounds per square inch. The diameter being 6½ inches, the area is 33·18 and the piston pressure 33·18×56·64=1,879 pounds. If the air should be cut off at ⅛ instead of 1/16, the mean pressure would be 6·158, and the crank pressure 3,064.

There are 2 cylinders, cranks at right angles, one at full stroke when the other is on its center. The weight of the car loaded is 8 tons. There are four wheels connected. Weight on drivers 16,000, adhesion one-fifth=3,200 pounds. The radius of the wheel is 14 inches, and of the crank 6½ inches, then 3,200×14÷6·5=6,880 pounds to be exerted on the crank, not allowing for friction of machinery, if it be required to slip the wheels on a dry rail. Or, stated in other terms, the power of 1,879 pounds at the crank is equivalent to 871 at the rail, and 3,064 at crank to 1,422 at rail.

The power of the motor cylinders with ordinary consumption of air is therefore insufficient to slip the wheels on a dry rail, but with street motors so large an amount of cylinder power as would be required for that purpose is unnecessary: owing to the frequent bad condition of the track, a large surplus of adhesion is required. The cylinder power can be increased fourfold by admitting a full cylinder of air, but this would be objectionable, as causing waste of air and noise from exhaust.

With a small motor of 6 tons the adhesion would be reduced to 2,400 pounds, and the crank pressure required to slip the wheels to 5,160 pounds. The adhesion in ordinary conditions of the rail is, therefore, as it should be, in excess of the cylinder power, and the wheels can slip only in consequence of ice and snow. It remains to determine the power for propulsion on a straight and level track and the power required on grades.

The traction of ordinary railroad trains is 9·2 pounds per ton on a straight and level road, based on the regular business of the Pennsylvania Railroad, but with a street motor it is said to require about 25 pounds per ton; 8 tons require 200 pounds, and this resistance, acting on a lever of 14 inches from the axle, while the propelling power acts with 6½ inches, will increase the power on the crank to 200×14÷6·5=430 pounds.

As the power on the crank with the 8 ton motor is 1,879 pounds, it would be sufficient to move four such cars, or 32 tons, on a straight and level road, not allowing for friction of machinery and losses in transmission of power from the crank, if, as has been stated, the traction does not exceed 25 pounds per ton, upon which this estimate is based. It is found that when dry air is used and the machinery is cold, the pressure of the air by gauge indications being 20 lbs., it required the full head to propel the car, while, where warm air was used, the car moved when the gauge indicated considerably less pressure.

Twenty pounds pressure is 1⅓ atmospheres. The average mean working pressure is 3·776 atmospheres. Twenty pounds produces 625 pounds crank pressure, or 300 at rail, and if this amount was required to overcome friction and move the motor, it would be equivalent to 37½ pounds per ton instead of 25 pounds, and absorb 50 per cent. more power than has been allowed; but it is stated that there was a back pressure at the time of several pounds per square inch, in consequence of the small size of the exhaust ports, which would cover a considerable part of this difference. It is possible, therefore, that, with the air heated, the traction may not exceed 25 pounds per ton, but it would be well to test both the traction of the motors and of ordinary cars by a dynamometer.

Fig. 3

SEBERTS PROJECTILE VELOCIMETER

GRADES.

It has been shown that if air is admitted into the working cylinder at a pressure of 16 atmospheres, cut off at one-sixteenth of the stroke and expanded to atmospheric tension, the mean pressure on the crank would be 1,879 pounds, and the equivalent to overcome resistance at the rail 871 pounds, capable of moving on a straight and level road, if all could be utilized, 4 cars of 8 tons with traction of 25 pounds per ton, and certainly 2 cars.

Also if the air should be cut off at ⅛ the mean crank pressure would be 3,064 pounds and the equivalent at the rail 1,422 pounds, capable of moving 4 such cars upon a level. As the angle of friction with traction of 25 pounds per ton is 66 feet to the mile, the 8 ton motor should be able to haul twice its own weight on a grade of 66 feet or 2 cars, on a grade of 132 feet 1 car, but 2 cars could be hauled by increasing the amount of air and cutting off say one sixth instead of one-eighth.

The 8 ton motor without extra cars attached should be able to overcome the steepest grades usually found on horse railroads. The steepest grade on the Second Avenue Railroad is said to be 230 feet to the mile, or one in twenty-three. The power with a full cylinder of air would be about 8 times the average power expended in working, and consequently the reserve is large enough to overcome great resistances of limited duration.

SMALL MOTORS OF FIVE TONS WITH CARS ATTACHED.

It would be a most serious disadvantage if the general introduction of pneumatic motors should require the abandonment of the old plant. Fortunately such abandonment is not only unnecessary, but the best possible system for

the economical operation of a line and for the accommodation of the public consists in the use of small cars and coupling two or three in a train under one conductor, at hours when the travel requires it.

Suburban residents desire frequently to make social visits or to attend lectures or places of amusement in the neighboring cities, and can testify to the discomfort, not to say danger, of riding home late at night with one foot on the platform and the other in space.

The ordinary horse car, loaded, weighs about five tons; the motor would weigh about the same, or with six tons would admit a large increase of cylinder capacity; there would then be no pretext for objection on the ground of injury to track. It could run with one car in the middle of the day, and morning and evening with two or three under one conductor. It could make the trip in half the time, certainly in two-thirds, of the horse-car, and take the place of 15 horses, the sale of which would pay for the motor, so that there would be no expenditure whatever for street motors, and nothing except for engines and compressors at the station.

The small motors weighing six tons would have the same cylinder power as the eight ton motors previously described, which gives 871 or 1,422 pounds at the rail, as the air is cut off at $\frac{1}{16}$ or $\frac{1}{9}$ of the stroke. The adhesion with dry rail is 2,500 pounds, and the traction of the motor at 25 pounds per ton $6 \times 25 = 150$ pounds.

If these small motors should be used to haul ordinary horse cars it becomes necessary, in estimating the performance of the motor, to know the traction of such cars. For obvious reasons this traction must be less per ton than that of the motor and yet more than that of ordinary railroad cars, which is nine pounds per ton. Probably 15 pounds per ton would be a full allowance for the traction of ordinary horse railroad cars, and a train of one 6 ton motor and two ordinary cars of 5 tons, each loaded, would make the weight of the train 16 tons and the traction 300 pounds, an average for the train of 18·8 pounds per ton. And 18·8 pounds per ton traction would give the angle of friction at which the train would descend by gravity $= 44\frac{1}{2}$ feet to the mile.

The train of one small motor and two cars could ascend grades of 178 feet to the mile, and with one car grades of 240 feet to the mile, and steeper grades could be overcome by using more air.*

The separate motor, not intended to carry passengers, except perhaps on top, would permit an increase of reservoir capacity from 160 to 225 cubic feet; and if reservoirs be placed also under the seats of each car the capacity of a two car train with motor would be extended to 325 cubic feet or doubled, and the run to 12 miles. If in addition, in speculating upon the possibilities of the future, the reservoir pressure should be increased to 500 pounds, instead of 350, the run would be extended 43 per cent. or 17 miles, and with one car attached to motor instead of two, still further. For working elevated railroads as a substitute for steam, the pneumatic motor is the perfection of a propelling power. The motor itself could be filled with air reservoirs, giving, with the addition of reservoirs under the seats of the cars, unlimited capacity, and there is no run within suburban limits that would be beyond the power of the motor, with a single station in the middle of the road to enforce the pressure. The cost of fuel would be reduced fully 66 per cent., and noise, dust, steam, and sparks from motor avoided.

If a motor should run off the track, it has power to run itself on the street pavements and can readily be replaced by the aid of crow-bars. If the machinery should become deranged, another motor could push it, and by a simple hose attachment the air in the disabled engine could work the machinery of the helper.

THEORETICAL TEST OF COMPRESSORS.

It is claimed that 50 horse power for 100 horse power of compressors can be actually utilized from the air when compressed. This will be tested.

There are two steam cylinders at the Second Avenue compressor, each 12 inches diameter and 3 feet stroke. The first compresses air to one-fifth or 5 atmospheres, and the second cylinder to one-fifth again, or to 25 atmospheres, and the second cylinder is one-fourth the area of the first.

In compressing to one-fifth, the mean pressure is ·522 of initial, and the resistance in first compressor is $5 \times \cdot 522 = 2 \cdot 61$ atmospheres throughout the stroke. The resistance in the second compressor is $25 \times \cdot 522 = 13.05$, and as the area is $\frac{1}{4}$ of the first compressor the comparative work is $13 \cdot 05 \div 4 = 3 \cdot 26$ atmospheres, and $3 \cdot 26 + 2 \cdot 61 \div 2 =$ average pressure in both $= 2 \cdot 94$ atmospheres. The steam pressure 80 pounds $= 5 \cdot 33$ atmospheres must be cut off at about $\frac{1}{9}$ of the stroke to balance resistance of compressors, omitting friction for the present.

The air is compressed at each stroke to 25 atmospheres in a six inch cylinder, if pumping into a tank under that pressure.

An expenditure of 3 feet steam in one cylinder at 2·61, and 3 feet steam in second cylinder at 3.26 atmospheres, is equivlent to

$$3 \times 2 \cdot 61 = 7 \cdot 83$$
$$3 \times 3 \cdot 26 = 9 \cdot 78 = 17 \cdot 61 \text{ atmospheres, 1 foot.}$$

The air in the first cylinder was compressed into one-fifth, and in the second into one-fifth more of an area $= \frac{1}{4}$. So the result will stand—

$$3 \text{ ft.} \times \tfrac{1}{5} = \tfrac{3}{5} \text{ and } \tfrac{3}{5} \times \tfrac{1}{5} = \tfrac{3}{25},$$

and $\frac{3}{25}$ with $\frac{1}{4}$ area $= \frac{3}{25} \times \frac{1}{4} = \frac{3}{100}$ at 25 atmospheres, $\frac{3}{100} \times 25 = 2 \cdot 35$ atmospheres, one foot as a basis of computation.

Cut off at $\frac{1}{15}$ the mean pressure is ·169, and expanded to atmospheric tension, the work done by the air under tension of 25 atmospheres is $2\frac{1}{4} \times \cdot 169 \times 25 = 9 \cdot 5$, as compared to the work in compressing it, which is 17·61, or ·54 per cent. of the power expended, omitting friction.

It does not seem possible, therefore, with the plans now used, to get quite as much as 50 per cent. from the compressed air when friction is considered and when the air is pumped into a tank, as this calculation supposes, against a resisting pressure of 25 atmospheres; but if the air should be pumped into the car reservoirs directly where the pressure at the commencement would be comparatively low, and the percentage of useful effect greater, it can readily be conceived that the claim of fifty per cent. duty may be fully sustained, particularly as the pistons move with great ease and the air compressors are self-lubricating.

EFFECT OF INCREASING COMPRESSION TO FIFTY ATMOSPHERES.

In compressing air from one to twenty-five atmospheres the heat liberated has been 534 degrees, but in reducing the volume again to one-half, the additional heat evolved would be only 116°. In compressing air from 25 to 50 atmospheres the mean pressure would be 42 atmospheres, and if the stroke should be 3 feet the work done in compression would be represented by $3 \times 42 = 126$. Omitting friction and thermal considerations, if this air were compressed by the direct action of steam upon a piston, the pressure being say 5 atmospheres, the area of the piston must be ten times the area of the piston of the compressors, and a full cylinder of steam would be required to overcome the maximum resistance of the air under 50 atmospheres, and the work would be $50 \times 3 = 150$ in the steam cylinder to secure an amount of work represented by 126 in the compressor, and which would also represent the amount of work done in the subsequent expansion. But with a double acting compressor and fly wheel the power required would not greatly exceed the mean pressure during the stroke, and the loss would be but little more than that which was due to fricton, and therefore the percentage of useful effect would be greater at high than at low pressures, provided it could be as fully utilized in expanding. If expanded without work to the tension required for the ordinary cylinder pressure there would be a great loss of power, and the only benefit that would then result from the increased pressure would be reduced reservoir capacity for a given run, or an increased run with a given capacity.

CAPACITY OF COMPRESSORS AT SECOND AVENUE STATION.

The compressor at Second Avenue station is rated at 100 horse power. It develops 66 horse power at mean pressure of steam and 73 strokes per minute. The smaller cylinder is 6 x 36. Its cubic contents, six tenths cubic foot, and its average of 73 strokes will deliver 44 cubic feet per minute at 5, and about 9 at 25 atmospheres.

A car containing 160 cubic feet, one-third full, will require 106 cubic feet at 25 atmospheres; but as the engine will pump against 8 atmospheres at the commencement instead of 25, the car reservoirs will fill more rapidly at first and the average time should be 7 minutes, or allowing for attaching and detaching, 9 minutes, which is said to have been the exact time required.

To charge one car per minute would require a plant of 500 horse power, which can be furnished at a cost of $20,000; but if trains of three cars are run at intervals of three minutes a smaller sum will suffice for engines, compressors, and boilers.

Considering the fact that trains on elevated railroads stop only at stations comparatively far apart, while surface roads may stop at every crossing, the average passenger will be much better accommodated with the pneumatic motor on surface roads than with the elevated railroads, and the difference in time will be trifling.

Where these motors are introduced elevated railroads will never be constructed. The wants of the public for rapid, cheap, and convenient transit will be met in the best manner possible by the surface roads now existing.

TO REMOVE ICE AND SNOW FROM THE TRACK ON STEEP GRADES.

The only real objection to street motors, and this applies equally to those propelled by steam and air, is that on very steep grades covered with ice and snow, the adhesion may be so much reduced that the motor cannot be operated.

A remedy suggests itself. A car may be placed in front of the motor containing cylinders with water under 80 pounds pressure, or 380° of temperature, to be used in melting and running off the ice and snow.

The heat required to melt ice or snow will raise an equal weight of water from 32° to 140° = 108°. 108 heat units are therefore required to melt one pound of ice. Tanks containing 160 cubic feet of water at a temperature of 328° will hold $328 \times 625 \times 160 = 3,280,000$ heat units, capable of melting $3,280,000 \div 108 = 30,000$ pounds of ice.

Suppose the snow and ice were of such depths as to be equivalent when melted to one inch of water, 8 feet wide. One lineal foot would contain 42 pounds, and 30,000 pounds would require 700 feet of track, which is the distance cleared by water of one car.

The cost of coal for these 700 feet of track at 8,000 heat units per pound of coal at $4 per ton would be 410 pounds coal at $4 per ton = 81 cents. This would probably be the cheapest possible way of melting down and removing ice and snow from tracks. There should be drains of tile or metal under the tracks on steep grades with frequent grated openings to allow the water to run off into the sewers and escape before again congealing.

I have assumed that the whole track, 8 feet wide, is to be cleared, but this is unnecessary for the purpose of securing adhesion; one foot wide at the rails might be sufficient.

It might be preferred to construct cars specially provided with tanks for this purpose. This is immaterial, but the weight must not exceed the power of the motor on steep grades, unless, which is very probable, it may be deemed expedient to construct a machine specially adapted to this purpose and hauled by horses to clear tracks in advance, an arrangement the utility of which is well worthy the consideration of all horse railway companies. The hot water should be discharged under pressure in the form of spray, and to furnish this pressure, when the temperature falls to 212°, a receiver of compressed air should be provided to be turned on when and as required.

Practically all the heat units could not be utilized, but it might be possible with 160 cubic feet of water to clear 400 or 500 feet of track at a cost for fuel of 16 to 20 cents per 100 feet.

Possibly it may be found advantageous to combine the hot water with the shovel or snow plow, to shovel off the bulk of snow and melt the ice which adheres to the rails and destroys adhesion. A car of water in this way would clear a very considerable length of track. In extreme cold weather a thin film of ice may form on the rail. For this I see no remedy better than the ordinary sand-box of the locomotive.

These are crude suggestions, given for what they may be worth, but I have endeavored to anticipate and meet every possible objection to the motor. I can see none except the want of adhesion in winter on steep grades, which applies in common to all other motors, and even to horse-cars, preventing the proper action of the brakes; but, if every other plan fails there is one resource that never can fail, the shovel, and this must be used even with horse power, and very frequently in severe winters. The extraordinary saving in cost of motive power will greatly overbalance any difference in disadvantage caused by the winter obstructions of ice and snow.

The officers of the company have submitted what I regard as an exceedingly modest estimate of the cost of power, as compared with horses, in which it is stated as 2 to 1 in favor of compressed air. If, as has been claimed elsewhere, ordinary steam motors save one-half the cost of power over horses, and if my figures are reliable, showing in consumption of coal more than 3 to 1 in favor of compressed air as compared with ordinary steam motors, then it would follow that the cost for power alone would be 6 to 1 in favor of air as compared with horses.

Do not misunderstand me: I refer to power alone; general, office, and other expenses are unaffected; but power is by far the most serious. The estimate was, moreover, made on dry air before the heater had been added, which so largely increases the percentage saved.

A few minor points in favor of the motor will be stated. Skilled engineers are not required to run them; a man of ordinary intelligence can learn to run these motors in a single trip. What is a most remarkable and beautiful feature of the contrivance is that a driver, however ignorant or careless he may be, cannot fail to use exactly the proper amount of air for the resistance to be overcome, and cannot waste it. If he admits too little, the car slackens speed or stops; if too much, he must shut off the brake. All is done by the movement of a lever, back or forward; no other brake is needed, and the motion of the car is a perfect governor.

This arrangement, amongst the many beautiful mechanical devices of the motor, impressed me as one of the most remarkable. I was apprehensive at first that very skillful drivers would be required to prevent a wasteful expenditure of air. I now perceive that a careless driver could not waste it if he would, unless by risking his neck by running at high speed down steep inclines. Another advantage of the motors is that the view of the track is unobstructed and can be seen from the platform on which the driver sits, while horses obstruct the view of the track for 30 feet.

On a level track the car can be stopped within its length when running at a speed of 12 miles per hour, and on grades in a time longer or shorter in proportion. The brake can never be out of order so long as the car has the ability to move at all. The brake consists in a full or partial reversion by moving a lever.

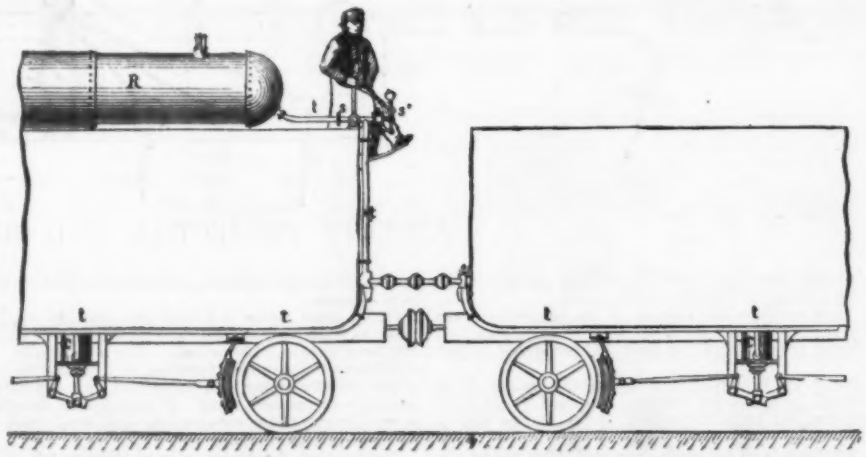
If the lever should get out of order, which is scarcely within the bounds of possibility, the car could not move at all, therefore the brake cannot fail. I noticed also in running along the Second Avenue Railroad on the motor that horses on the opposite track meeting the motor would sometimes shy, but other horses not on the track did not notice it. The car horses would, no doubt, soon become accustomed to the motor, but as its general use would soon supersede horses altogether, the fact is of little consequence.

(To be continued.)

* Since the above was written further experiments have shown that the increased consumption of air by attaching horse cars to the motor is about the amount that could be supplied by reservoirs under the seats, and consequently that the distance run need not be diminished by attaching additional cars if so provided.

COLLADON'S SYSTEM OF COMPRESSED AIR BRAKES.

M. D. COLLADON communicates to the *Revue Industrielle* the accompanying illustration and description, drawn from his patent specification, to show that at least four-fifths of the Westinghouse air-brake are embraced in his (Colladon's) patent taken out in 1855. M. Colladon further states that he never pushed his invention, owing to his having been appointed engineer in chief in the construction of the large gas works at Naples, and also from the fact that many weightier matters have occupied his mind.



COLLADON'S SYSTEM OF COMPRESSED AIR BRAKE.

His system consists in the use of a special reservoir, B (see figure), which may be placed on either the locomotive, the tender, or a car, and which is to contain a supply of air or gas under a certain pressure that may be equal, superior, or inferior to the tension of steam in the boiler. The com-

pressed air or gas in the reservoir is kept at its normal degree of tension by means of a small force pump actuated either by the locomotive, the wheels of the train, or by hand; or the reservoirs may be supplied from secondary reservoirs kept at the different stations.

This reservoir, B, is furnished with a manometer, and an outlet tube closed by a cock or valve that the inventor calls a "stoppage valve." This valve is connected with a lever, a key, or a rod that may be easily worked by hand when it is desired to tighten the shoe-brakes to lock the wheels. To effect the tightening of the brakes by means of the compressed gas, each car is provided with a cylinder, C, containing a piston. The rod of the latter serves to press of draw the levers which move the shoes, and acts upon them like rigid bars, and not like vises as in the ordinary systems. Besides the cylinder, each car is furnished with a tube, *t, t, t,* open throughout its whole length, and its two extremities ending, one at each end of the car. This tube, which is about one inch in diameter, is made of metal or some impermeable material, and is flexible and tough enough to resist the pressure of the compressed gas. The two extremities of this tube are provided with hinge joints, elbow movements, or pieces connected by flexible tubes; they are each furnished with a cock or valve, and the ends are so adjusted that they may be quickly united by a screw or bayonnette joint, with the tubes of the other cars when the trains are made up.

From this disposition of the parts it will be readily perceived that when the brakeman opens the stoppage-valve. S, the compressed gas will rush forward through the whole line of tubes, and penetrate simultaneously all the cylinders, without condensing in them as steam would, and that its action on all the cylinders is in a measure instantaneous. The stoppage-valve may be furnished with a regulating apparatus to limit its degree of opening, when the engineman desires to fix beforehand the minimum time in which the complete checking of the train is to be effected. The outlet tube of the reservoir is furnished at a certain point beyond the stoppage-valve, with a blow-off cock, S′, which loosens the brakes by letting the compressed air escape from the cylinders.

FRENCH SYSTEM OF CAR HEATING BY PORTABLE HOT-WATER HEATERS.

In consequence of an order issued a few years ago, by the Minister of Public Works, the railroad companies of France found themselves unexpectedly obliged to apply some system of heating to all their passenger coaches, without distinction as to class. The Orleans Railway had been using, for its first-class coaches, a system of heating by means of a small portable apparatus, filled with steam-heated water, and all the other companies, except that of the East, had adopted the same method. In consequence of the edict above mentioned, the companies began experiments to find some means of hastening their method of heating, which, when applied to all of the coaches, seriously retarded the trains owing to the time consumed in changing the heaters at the station. Both systems have now been so perfected that the change of the apparatus is accomplished quickly, without confusion, and in perfect order—something that was not deemed possible when the question of a general heating by a portable apparatus was first discussed.

The system employed on the Orleans Railway consists in heating, by means of steam jets, the chilled water of a certain number of such metallic boxes simultaneouly without refilling. The steam used for heating is generated in high pressure tubular boilers at certain stations, and is introduced into the portable heaters by means of a special apparatus. The system in use on the railway of the East appears to be more expeditious, and possesses such novel features as to make it worthy of a more extended description, and it is as follows:

At the proper stations, wells are constructed of a depth of about 14 feet. A steam boiler which communicates with the bottom of the well maintains the water of the latter at a temperature of 100 degrees. This boiler also supplies steam to a small engine of 2 horse power, which puts in motion the drums of a "noria" situated at the north of the well. The foot warmers belonging to the coaches are placed each one on the two rests of the chain of the "noria," and the movement given to the latter by its drums is calculated so that the foot warmer is delivered at the side opposite to that at which it was introduced after an immersion of five minutes in the hot water. In fact, experience has demonstrated that a metallic box, of the capacity of the one represented in the accompanying cut, requires this length of time to reach 90 degrees in a bath which is kept at 100 degrees. The foot warmers are closed tightly, after once filling, with a screw cap provided with a rubber washer; the water lasts the entire season, and it is rarely that it has to be renewed. The heating of coaches by this method was begun in the winter of 1877, and the number of heaters put into service was more than eleven thousand. From the 8th of March to the 15th of May, 1877, the number of these heaters used on the railways of the East was 1,060,000. The time taken in changing the heaters of an ordinary train is 12 minutes. The following description of the accompanying figures will give an idea of the working of their system.

DESCRIPTION OF FIGS. 1, 2, 3, 4, 5, 6, AND 7.

Fig. 1. Vertical section of a hot water well for heating portable boilers filled with water, and profile view of the noria.

Fig. 2. Another vertical section showing front view of the noria.

Fig. 3. Transverse section of well and noria

A. Motor pulleys, put in motion by a small steam engine which also actuates the noria by means of a pinion and cog-wheel.

B. Upper drum of the noria turning in the direction of the arrows.

C. The portable heaters or foot warmers, placed on the rests of the two chains of the noria.

D. Side at which the chilled boilers are attached to the chains.

E. Side at which the boilers come up heated after an immersion of five minutes in the well.

F. Table for receiving the heaters as they come up out of the well. Here they are deposited automatically by a movement which will be explained further on.

G. Tube for conducting the steam into the well. This extends to the bottom, and allows the steam to escape through the middle of the water by a horizontal pipe pierced with holes.

H. H. Screws placed near the lower drum for regulating the tension of the chains.

Fig. 4. Profile view, in elevation, of the grooves for charging and automatically discharging the heaters. The large arrows indicate the direction in which the chain moves.

I. Side at which the cold boxes are charged. This objection is performed by hand.

J. Groove at the charging side, obliging all of the rests on the chain to take the position shown in the figure. The heater is presented by hand in the inclined direction shown by the dotted figure K, then inserted in the rests, which immediately carry it downward by the movement of the chain.

L. Side at which the heaters are discharged automatically.

M. Groove which tilts the heaters as soon as they appear above the table.

N. N. Flexible brushes between which every heater passes, thus ridding itself of moisture before being deposited on the table.

Fig. 5. General plan of the building at the Paris station.

O. Generator.

P. Water supply for the generator, O.

Q. Overflow pipe of the tank, P.

R. Feed pipe for the pump.

S. Hot water well.

T. Pipe leading steam from the generator, O, to the well, S.

V. Overflow pipe of the well, S.

V. V. Three wheeled cars carrying the coal boxes to the well.

W. W. Three-wheeled cars carrying the heated boxes from the well to the train.

X. Platform of the station.

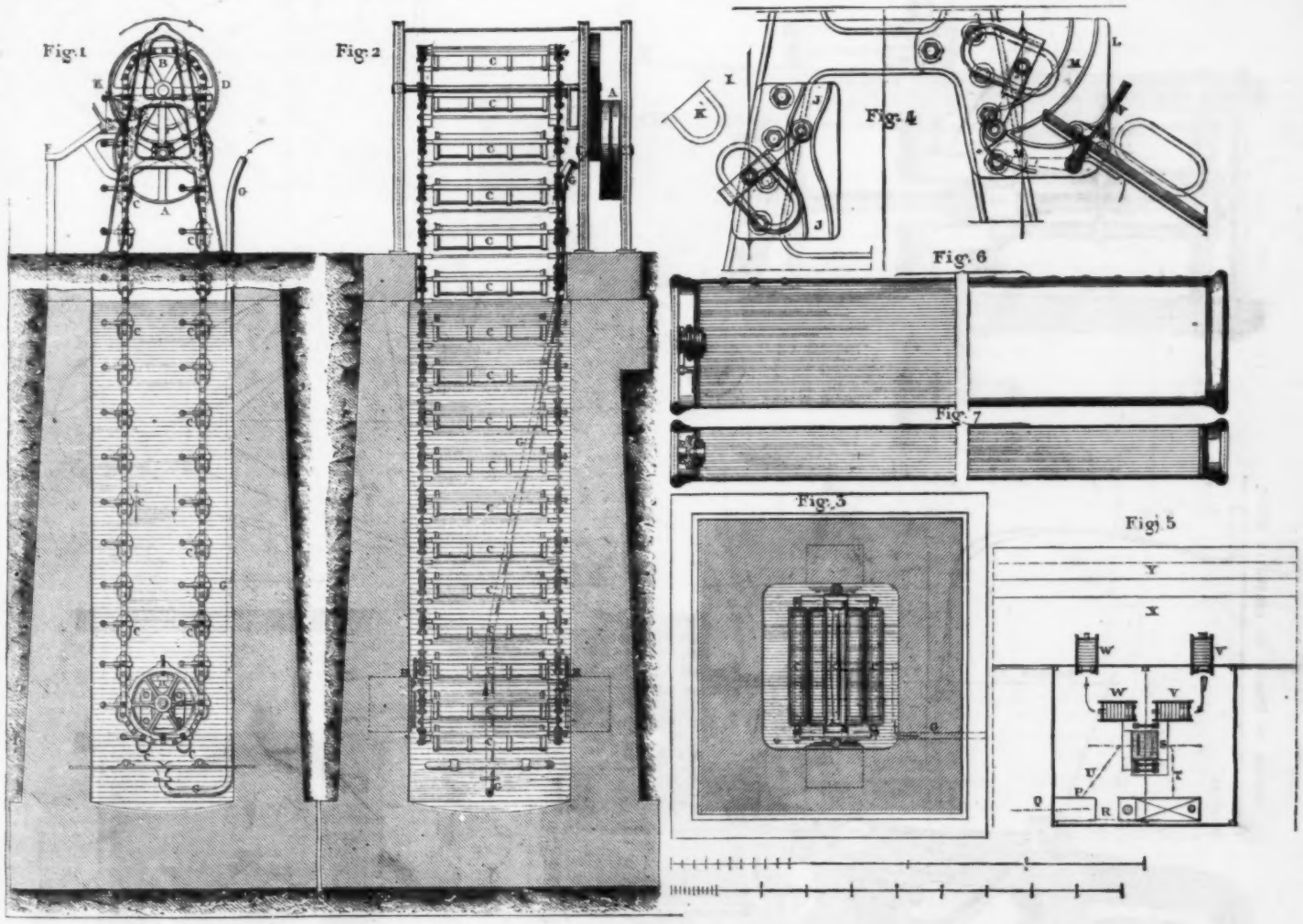
Y. Tracks of the railway.

Fig. 6. Longitudinal half section and elevation of a portable heater.

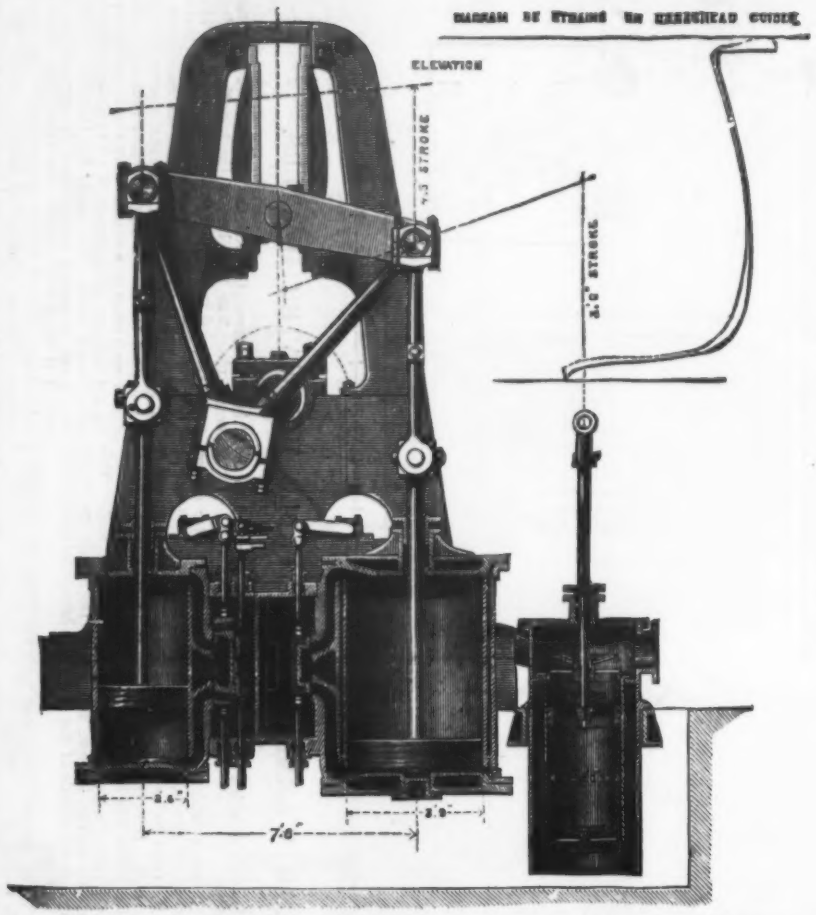
Fig. 7. The same seen in a plane perpendicular to that of Fig. 6.

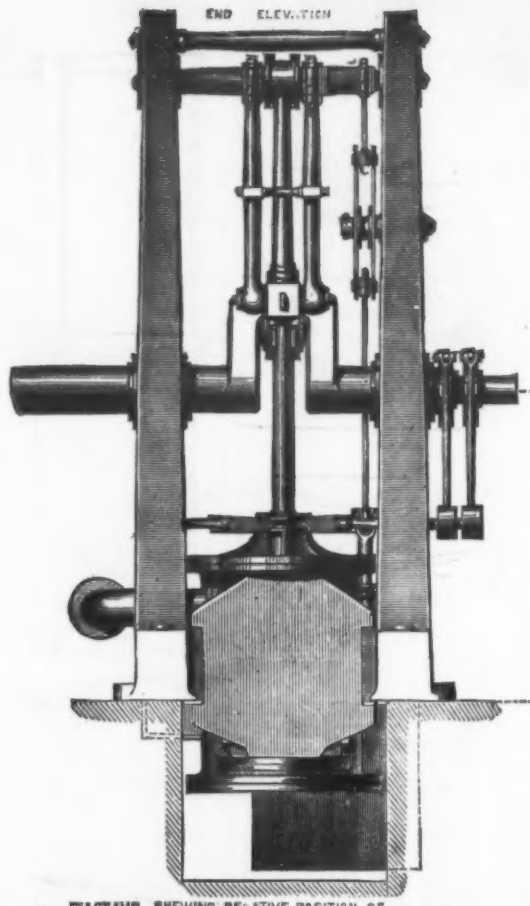
NEW TWIN CYLINDER STEAM ENGINE.

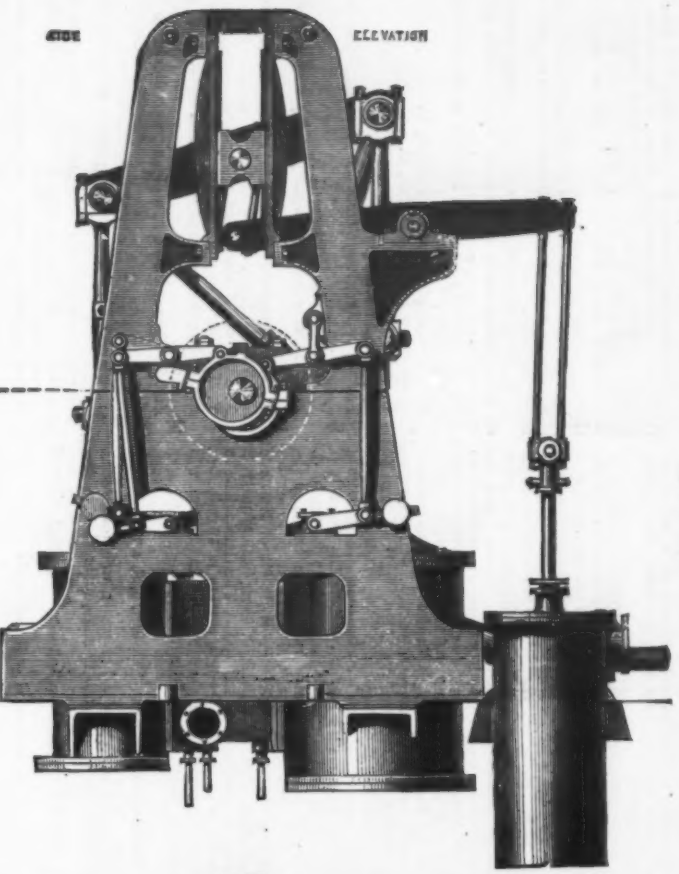
THE engine which we illustrate was designed by Mr. Joseph Bernays, of London, on a novel and peculiar principle, its construction being as follows: There are two upright cylinders, made in the present instance of unequal diameters for working steam on the high and low pressure compound principle, but this is not essential, and the cylinders may be of equal diameters, each using fresh steam. The cylinders stand a short distance apart, and the crank shaft is placed in the center line between them, and may be situated either above, below, or actually between the cylinders. The two piston rods are connected by links to the outer ends of a triangular connecting rod, the apex of which embraces the crank pin. The base line of the triangle opposite to the apex is guided in its center to move up and down in regular cross-head guides, and can also swing around that center. As the crank shaft rotates, it causes the connecting rod to rise and fall with the crank, and at the same time to oscillate around the cross-head pin, which causes the pistons to follow each other in a manner very similar to that produced by the ordinary arrangement of two cranks set at right angles to each other. The engine has therefore no dead center; it can be started and stopped in any position, and reversed if fitted with suitable reversing gear. One of the advantages claimed by this arrangement is its great compactness without cramping or reducing any of the details, combined with the use of upright cylinders which are not so likely to wear unequally as horizontal ones. The engine

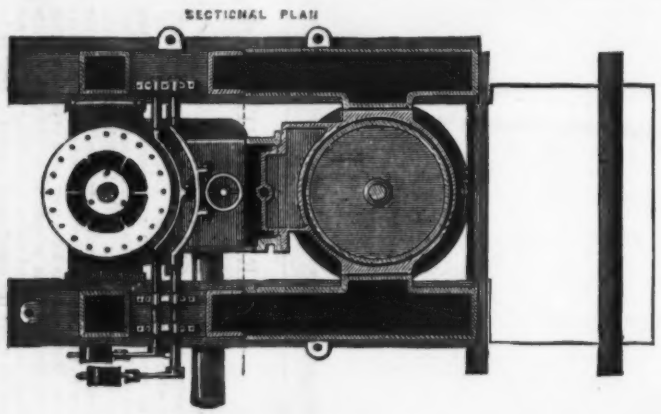


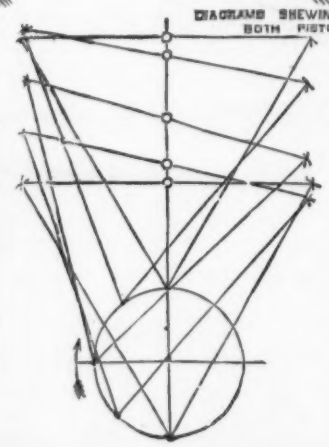
FRENCH SYSTEM OF CAR WARMING BY PORTABLE HOT-WATER HEATERS.

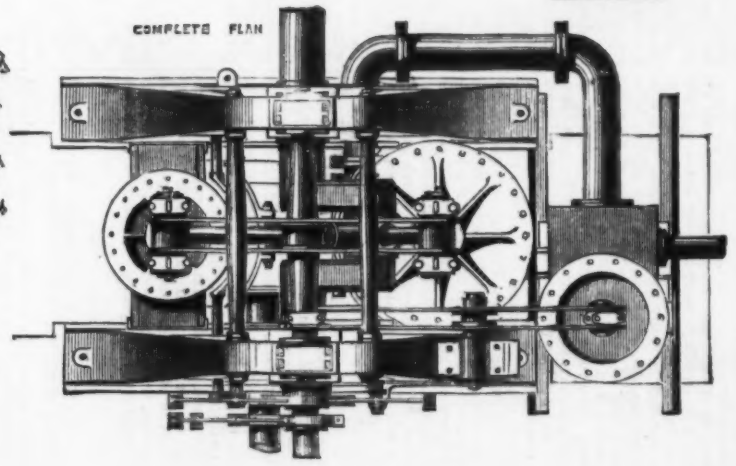












BERNAY'S NEW TWIN CYLINDER ENGINE.

shown in our drawing will take up only about from one-third to one-fourth of the floor space required for an ordinary pair of horizontal engines with cylinders of the same size, and the weight also is considerably reduced.

It will be instructive to follow the motion of the crank around the circle. In the longitudinal section, page 2816, the piston of the low pressure cylinder is in its lowest position. That position is reached when the crank in the lower half of its course moves in line with that side of the triangular connecting rod to which the low pressure piston is hung. The other piston is still a considerable distance up in the large cylinder on its downward course, and continues to turn the crank whilst the low pressure piston is at the dead point. As the crank continues in the direction of the arrow it reaches its lowest position, taking the smaller piston down with it and the larger piston up. The two pistons are at that moment at an equal distance from the lower cylinder ends, but the one piston having the steam on its upper, and the other on its lower surface, both tend to turn the crank in the same direction. When the small piston has reached the bottom the larger one is well up in the cylinder, and thus helps the other over the dead point, both then continuing their way up at regulated speeds until the same action is repeated at the upper end. Each piston reaches the end of its stroke up or down as that side of the connecting rod to which it is hung comes in line with the crank. From this it will also be seen that the length of stroke of each piston is greater than double the crank throw, which thus permits the use of a somewhat smaller crank forging for a cylinder of a given stroke.

It might be thought that the actions of the inclined parts of the connecting rod would throw a considerable strain on the cross-head guides. But such is not the case, inasmuch as the strains from both pistons oppose and partially counteract each other, leaving the free pressure on the cross-head no greater than in other engines of the same proportion.

Strange to say, the greatest free pressure on the cross-head guides occurs not in the middle but at the ends of the stroke, as is shown in the diagram, which is roughly constructed from a pair of equal cylinders working without expansion, in which these strains would be less favorable than in an engine working with expansion. The straight line represents the path of the cross-head, and the curve approximately the resultant of strains at any point at right angles to the movement, and it will be seen that throughout the largest part of the stroke the pressure is very moderate, and varies very little except near the turning points. But as the speed of the cross-head at those points is very small, the power lost through friction is quite unimportant, and the guides have a tendency to wear very evenly throughout their whole length.

The next point of interest in the construction of this engine is the valve motion. It will be remembered that when the crank is at its highest or lowest position, neither of the pistons is at the end of the stroke, the one having already past and the other not yet arrived at that place. All other positions of the pistons in reference to the angular position of the crank are equally different from those experienced in an engine of the ordinary construction, and it is therefore impossible to employ the ordinary eccentric motion for the proper distribution of the steam in both cylinders. It is necessary to employ a triangular connection between them and the eccentric, similar to that which is used for the pistons and the main crank. This has been accomplished very simply by providing the eccentric ring with two eyes, to which the levers which move the valves are hung. The distance between the two eyes, as also that from the eyes to the center of the eccentric, bears the same relation to the throw of the latter as the dimensions of the main connecting rod bear to the throw of the crank. One eccentric only is required for working both valves, and where separate expansion valves are used a second eccentric works the expansion valves of both cylinders. In engines in which link-motion is used for reversing, two eccentrics only are employed instead of the ordinary four.

When an engine of this description is to be applied to marine purposes in connection with a screw propeller, the crank shaft is placed low down between the cylinders, and as there is no room then for the crank to work in the space left between the cylinders, it is made double, each half being fitted with its connecting rod. Such an engine has the center of gravity low down, it weighs little, as no heavy frames or standards are required, it takes up little room in the vessel, and all vulnerable parts are well below the water line, an important consideration with vessels belonging to the Royal Navy.

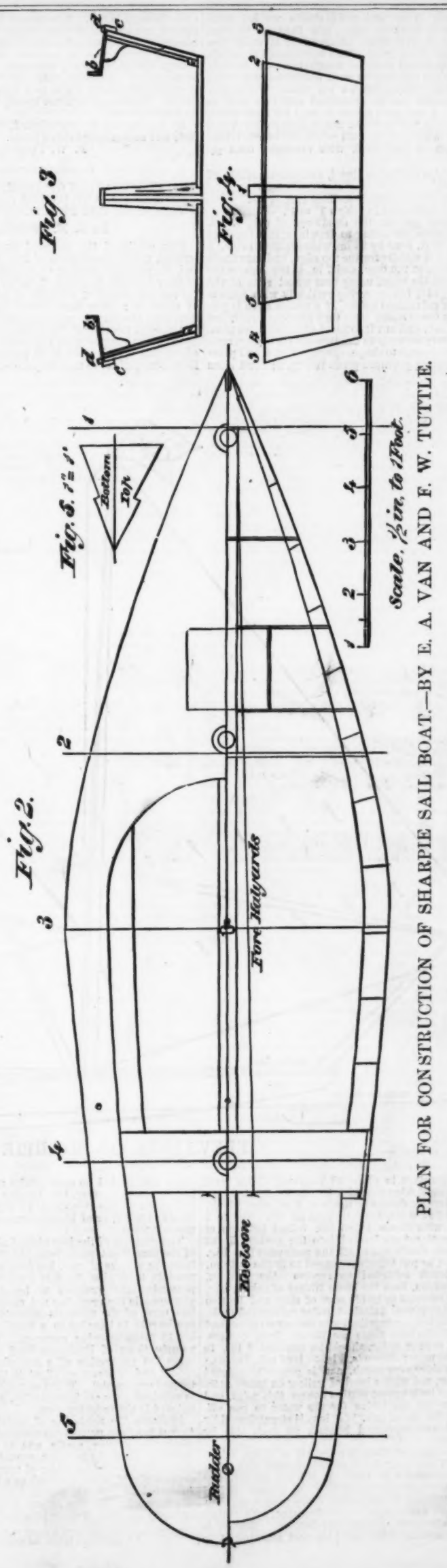
The engine shown in our illustration is intended for a mill or factory; it has a high pressure cylinder of 30 in. diameter by 4 ft. 6 in. stroke, fitted with variable expansion valves, which can be altered whilst running. The low pressure cylinder is 45 in. diameter by 4 ft. 6 in. stroke, fitted with a steam jacket. The air pump is worked by means of a lever from the cross-head pin. With steam at 50 lb. pressure expanded five times, and a speed of about forty-five revolutions per minute, the engine is designed to indicate about 500-horse power.—*The Engineer*

SHARPIE MODEL.

By E. A. VAN and F. W. TUTTLE, O. C., Oneida, N. Y.

THE Sharpie, both in model and rig, is but little known beyond Fair Haven, Conn., and vicinity; but when once introduced is sure to become a general favorite, being very cheaply and easily built. Almost any one with a few tools can build, at small expense, a really good sail boat or steam yacht on this plan, giving much more room for machinery and crew than the more costly "Carver" or "Clinker" built boats, of like dimensions, while for speed and seagoing qualities, Sharpies are excelled by none. For lake and river sailing they will be particularly appreciated by the sportsman, as their light draught permits them to run on the "sweat of a water pitcher" almost, enabling the boatman to follow his game in the marshes and shallows where deep keels stick fast in the mud.

Fig. 1 is a sail draught showing racing rig. Masts and sprits are of spruce, well varnished; sails of Boyle's yacht drill, with two rows of reef points; brass grommets are inserted in the edge next the mast for lashing sail to mast hoops; these are best made of hickory, though galvanized iron or brass may be used: also three large grommets are worked in outer edge of sail to receive end of sprit; the lanyard for holding inner end of sprit should be fastened to a mast hoop so as to run down when sails are lowered. The sails may be lashed to the mast and furled by rolling up on the sprit; this is cheaper and is generally done for small sails. Best manila rope, $\frac{3}{4}$ in. diameter, is used for bolt ropes, sheets, and halyards. The fore halyards are led aft under the deck, and made fast at foot of mainmast near main halyards, so as



to be in easy reach. Fore and main sheets are led from rings on port side to block on sprits, and then aft to cleat on starboard side of after deck. Main sheet is made fast and fore sheet held in the hand. The boat should be so balanced on her centerboard as to be handled almost entirely by the foresheet, and the celerity with which she will come about is equaled by nothing but an ice boat. For heavy weather the mainmast can be unshipped and fore used in the middle step. A balanced rudder is used for large boats, but a 12 or 14 ft. oar will be found much handier for quick work in shallow water, or to scull when the breeze fails.

Fig. 2 is a plan of port deck with starboard deck removed.

Fig. 3 is midships section on line 3, and shows section of centerboard trunk.

Fig. 4 gives transverse sections at lines 1, 2, 3, etc.

Fig. 5. Plan of deadwood in which 1′ = 1′.

To build this boat, get out the deadwood of oak, 30 ins. long by 12 ins. square, according to drawings; then the sides of ⅞ clear pine, 20 ft. long by 24 in. wide are first made, 3 ins. hollowing in the middle for the top edge, and then made straight 24 ins. wide at the bow, and 7 in. at the stern on the lower edge. Build the stern, using bent wheel rims of the proper sweep, 1½x1½ ins., covering vertically with narrow pine, put on with galvanized nails. If a square stern is preferred, and being much easier built they are often used, get it out of 1½ in. oak, and cut it to place after sides are bent. Fasten the sides very securely to deadwood with brass screws 2½ in. No. 10; cut boards to shapes given in Fig. 4, and place them in corresponding positions given in Fig. 2; bend sides drop through below. Afterthwart is of 2 in. plank; a 2 in. thwart, not shown, should form the upper bearing for foremast in first and second steps to relieve the deck of strain. A hatch gives access to forward deck for stowage or just enough ballast, should it be needed, to keep her nose 2 inches in the water. A locker under after-deck is best place for stores, as the boat is apt to be a little wet forward in a stiff breeze. Seats may be fitted loosely for passengers or removed when desired.

By leaving out the centerboard, the Sharpie makes a safe, fast, and commodious steam yacht.

F. W. TUTTLE, O. C., Oneida, N. Y.

THE INOXIDATION OF IRON, AND THE COATING OF METALS AND OTHER SURFACES WITH PLATINUM, BY THE PROCESSES OF MONS. DODE.

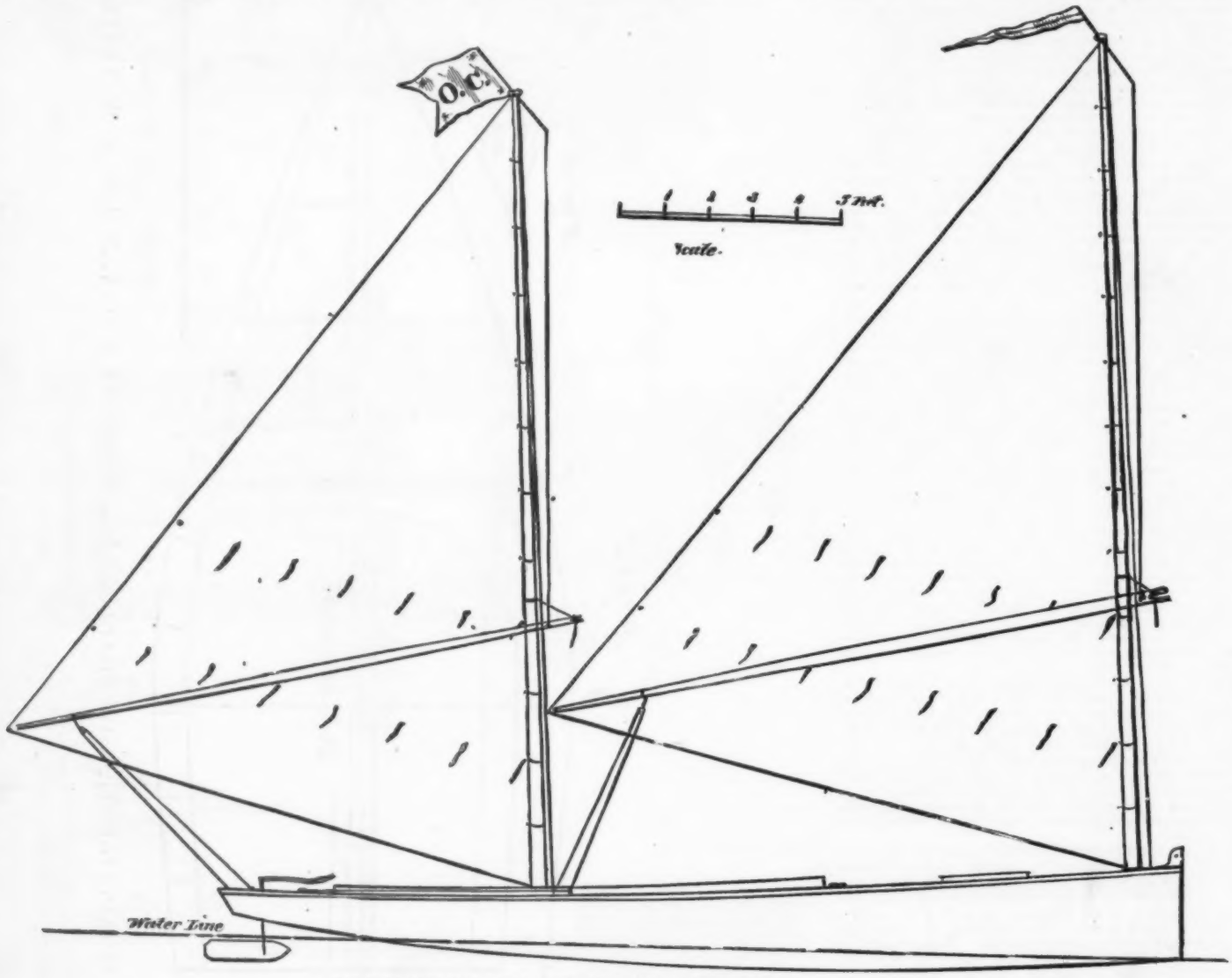
By L. M. STOFFEL, C.E.*

THE origin of the patented processes, about to be described, for the inoxidation of iron, the enameling of metals, and the platinum coating of metals, arose, incidentally, out of the researches in which M. Dodé had long been engaged, for the application of chloride of platinum to the silvering of glass, in a form that should supersede the deleterious mercurial processes in common use.

Although the title of the present paper contains reference to the platinizing of glass and other substances, it is intended, on this occasion, solely to confine the description of M. Dodé's inventions to their application to metal surfaces. At the objectionable oxide or rust upon the surface treated. On this the metal to be applied deposits itself. But the layer of oxide beneath the outer covering of metal is never entirely got rid of. It is always liable to affect the outer surface of the object coated, as may be frequently observed in galvanized iron, and in all cases the coating of deposited metal has to be of a sufficient thickness to counteract the spontaneous oxidation primarily due to the acid used in the galvanic process.

It seems to have been reserved for M. Dodé, a French chemist of repute, whose family have for several generations actively devoted themselves to metallurgical research, to perfect and patent processes successfully solving the twofold problem of the inoxidation of iron and the application of platinum to its surface in a practical and inexpensive manner.

The first process, "inoxidation of iron," consists in coating, either by means of a bath or a brush, any objects in cast or wrought iron (freed from the damp they may contain) with a composition consisting of borate of lead, oxide of copper, and spirits of turpentine. This application soon dries on the surface of the iron, and the objects are then passed through a furnace, which is heated from 500° to 700° Fahr., according to the thickness of the articles under treatment, so as to bring them to a cherry heat when passing through the center of the furnace. At this point, the fusion of the metallic pigment takes place; it enters the pores of the iron, and becomes homogeneously adherent thereto, covering the objects with a dark color, not liable to change through atmospheric, gaseous, alkaline, or other influences,



ELEVATION OF SHARPIE SAIL BOAT.

to them and secure stern in place with screws. Now level across with a straight edge the sides to receive the bottom. The centerboard trunk should be made of 2 in. pine plank, 22 ins. wide and 7 ft. 6 ins. long, thinned on top edge to 1 in. (see Fig. 3), with pieces 1½x3 ins. bolted between at each end. These pieces are framed into the keelson 5¼x3 ins., running from deadwood to aft the mainmast (see Fig. 2). These should be put together, shaped to fit the bottom, the sides of trunk rabbeted to receive the bottom, and placed in position, then the lower ribbon of oak (*a*, Fig. 3), 1½x3 ins., is screwed to inside edge of side, and bottom of ⅞ cedar or pine is well nailed on, using galvanized nails. Ribs of oak 1x1½ ins. are mortised into the lower ribbon and cut off even with the top; these are 15 ins. from centers. The deck, of ⅞ pine or cedar, should be rounded 4 ins. to shed water. The upper ribbon (*a*, Fig. 3) is of oak, 1x3 ins.; this stiffens the sides very much, and is generally painted some bright color, red with a bead of yellow on lower edge. A half round one inch square section covers this joint, and scupper holes are cut amidships for the water to run off. The combing (*b*, Fig. 3), of oak, ½x3 ins., is strengthened by a quarter round, and supported beneath on each side by brackets or knees.

Centerboard is made of Georgia pine, 2¼ or 3 ins. wide, 1 in. thick, and 7 feet long; it is doweled together with brass rods and may be bound with iron. It is hung on a pin at the lower edge forward, and raised by a rod jointed to fold down on top of trunk. Should shove down three feet. For rudder fillings use water pipe, 1 in. diameter, with collars screwed to fit water tight on deck and bottom. Rudder is unshipped by removing tiller and pin, and allowing it to

some later period an opportunity may be afforded of treating, in another paper, the bearing of two of the processes concerned in the treatment of glass, whether in form of sheets or tubes, or of blown or moulded objects, and also of ceramic ware.

The problem of the inoxidation of iron, or, in other words, of the permanent preservation of that most useful of metals from the attacks of rust, has long occupied attention. The possible utilization for this purpose of platinum—a metal possessing the qualities of being entirely unaffected by atmospheric changes—has not escaped research. Nevertheless, none of the attempts hitherto made in this direction can be said to have led to a practical result, or one applicable to manufacturing purposes. The two latest of these, namely, those of Professor Barff and Mr. Bower, depend upon the production of a superficial coating of magnetic oxide; and, however excellent in their way, can scarcely be termed ornamental. When any other color than bluish gray is required, they are inapplicable, and the material has to be painted in the ordinary way.

Hitherto, the rendering of metallic objects impermeable to rust has been partially accomplished by means of electroplating—a lengthy, costly, and in many cases inapplicable method. Iron, for instance, cannot be electro-silvered without an intermediate coating of copper. Moreover, cast iron articles placed in an acid bath as a preparatory step to being subjected to galvanic action, have their fiber irretrievably deteriorated. The first action of the acids employed in the ordinary galvanic process is actually to form a coating of

* A paper read before the Society of Arts, London.

nor to disintegrate from the surfaces to which it has been applied. When any considerable depth of inoxidation is desired, the object may be immersed in the composition for the time requisite to absorb a sufficient quantity thereof. Corrugated iron may be treated by means of the above described coating, which supersedes galvanizing, is of lesser cost, and is producible in several hues of dark color. This first process wholly supersedes painting and varnishing, and metallic objects thus treated are rendered impervious to rust, and hence are of much greater durability. The cost of application is computed at an average of ¼d. per superficial square foot.

The second process, "enameling of metals," consists in a repetition of the coating operation, but with a pigment differing from that above described, and having for its object the production of a smooth polished surface, such as is obtained with thick enamels. This pigment, which is composed of borate of lead, litharge, and essence of lavender, may be applied directly upon metal, and it renders iron also inoxidizable, although not to such a degree of perfection as when preceded by the first process. Its object is to supersede enamels, which it does most advantageously, with respect to cost and durability, while furnishing a smooth and even surface for receiving and effectually protecting the subsequent economical application of platinum or gold to articles thus treated. An extensive variety of colored enamels may be produced, separately or in combination. The cost of this process is computed at 1d. to 1½d. per square foot superficial.

The third process, "platinum coating of metals," is applicable to both of the inoxidating and the enameling pro-

cesses, but with this difference of result: In the first case the platinum yields the appearance of dull silver, and in the second it resembles this metal so highly burnished as to render any subsequent polishing wholly unnecessary. The dry chloride of platinum dissolved in ether, and held in solution by essential oils, is simply applied by means of a painter's brush or a bath, according to the ornamental effects desired, and by the simple aid of heat sufficient to cause the evaporation of the medium which holds the platinum in solution, a heat not exceeding 350° to 400° Fahr., the platinum becomes incorporated with the inoxidated surfaces. The result is that a relatively infinitesimal portion of platinum suffices to coat a considerable surface; while this metal, being unaffected by atmospheric variations, or by the products of combustion of gas, objects treated by M. Dodé's inventions are rendered unalterable by exposure, or by ordinary wear and tear. The cost of this last process varies from 1d. to 3d. per square foot superficial, according to the thickness of the metallic coating applied. When it is desired to produce a highly brilliant surface, two successive coats of the preparatory enameling are given, and an increased quantity of the platinum solution is applied. Gold, similarly prepared, may be used in lieu of, or in combination with, platinum, at considerably less cost than when employed for electro or leaf gilding. In the case of platinizing or gilding objects of polished metal, the first coating may be entirely dispensed with. No burnishing is required in order to produce a bright surface with this process.

With reference to the various degrees of heat which are essential to the successful application of M. Dodé's process, it is necessary to remark that, as the metal objects subjected to treatment are heated and cooled gradually by special furnace arrangements, and as the maximum duration of exposure to the greatest heat does not exceed five or six minutes, no detrimental effect whatever can possibly ensue.

By M. Dodé's processes, which substitute heat for galvanism, the use of acid is entirely dispensed with, and, there being thus no cause to encourage oxidation, no obstacle is offered to the instantaneous amalgamation of the original surface with the applied metal; a sufficient degree of heat only is required to cause the evaporation of the substances by which the latter are held in solution and fusion. The merit of the discovery lies in the method of preparing and holding the various metallic pigments in solution, and in directly applying them to the objects under treatment, with no other aid than such degrees of heat as do not affect the condition of the metals treated. Compared with electro-plating and galvanizing, these processes, by reason of their moderate cost and the facility of their application, present such advantageous features that a large field for operation is thereby opened.

In fact, the field offered in the industrial world for the practical application of M. Dodé's inventions may fairly be described as boundless. There is hardly any limit to the application of the processes save the size of the furnace, and hence they can be applied with equal facility, and by common mechanical means, to a metal paper-weight or a pillar letter-box, to a door-knob or to a park gate.

By the black or inoxidating process objects are rendered durable, by the enameling and the platinizing processes absolutely beautiful, and at the same time impervious to the effects of outdoor exposure. It is not too far, perhaps, to look forward to the day when galvanized iron roofs and buildings, in their gray unsightliness, will be replaced by sheets of softly glittering metal, pleasantly refreshing rather than dazzling to the eye, when lamp-posts, converted into gleaming pillars of silver, or gold, or bronze, shall reflect the luster of the flame they support, and when pillar letter-boxes, street orderly bins, and metal corner-posts shall combine the useful with the attractive. Iron railings, too, around public monuments and buildings, such as the British Museum, instead of requiring continual coats of paint, or having their spikes periodically covered with gold leaf at a great expense, compared with the effect and durability obtained, may be advantageously treated by M. Dodé's invention; for he contends that by the substitution of gold for platinum as the outer coating in his process, he can produce the effect of gilding at one-twentieth of the cost where gold leaf is employed, and obtain at the same time an infinitely greater durability. Here is an opportunity for the city or cathedral authorities to venture upon an experiment which deserves trying. The railings round St. Paul's Cathedral are to be redecorated, simultaneously with the improvement of the churchyard. Instead of adopting the present expensive method of gilding, why not coat them with M. Dodé's composition, at considerable saving in the cost?

In all cases cost is a most important feature of preservative operations, and it may be broadly stated, in reference to M. Dodé's method, that the cost of platinizing is about equal to that of applying three coats of paint and about one-tenth of that of electro-plating with nickel. These comparisons have reference to Paris prices, which, as a usual rule, are not lower than English. A detailed account of the treatment of eight stoves, one of which is now exhibited to this meeting, is as follows:

	Frs.
1 liter preparation (retail)	3·75
First furnace operation	3·20
Reagents for platinizing	4·00
Second furnace operation	3·20
Manipulation, wear and tear, etc.	1·85
	16·10

being two francs, or 1s. 8d. per stove. The French trade is quite willing to pay four times this rate, as to nickel-plate, a similar stove costs from thirty to forty francs; and the Val d'Osne Company, who are large manufacturers of these stoves, have expressed a highly favorable opinion of the results arrived at.

The preservation of iron ships from the action of salt water by means of M. Dodé's invention is a problem as yet requiring further investigation. But so far as a ship's numerous fittings, now made in brass or galvanized iron, are concerned, there can be no doubt of the superior strength and durability of metal treated according to his patent, and there would be no comparison between the strength of galvanized and platinized iron-wire for standing rigging. The insulation and preservation of telegraph wires, and the preservation of the ironwork portions of railway rolling stock, also deserve attention.

M. Dodé may, at least, be congratulated upon having successfully solved a problem that has been for a long time occupying the attention of the iron trade, namely, the opening up of a fresh field for the employment of wrought and cast iron. Ordinary cast or wrought iron preserved and decorated at a trivial cost, according to his methods, will replace, to a considerable extent, copper, nickel, brass, and other costly metallic substances hitherto employed. Large foundries, devoted to the production of ornamental metal work, are likely to accord an unfeigned welcome to a discovery which will enable them to preserve their manufactures from rust, obviate all necessity for periodical polishing whilst the articles remain in stock, and also enhance their appearance and, consequently, their value.

Articles of common use, and ornamental productions of high class, can be advantageously subjected to M. Dodé's processes at very moderate cost; while the market value of all objects treated is considerably enhanced, not only through their highly ornamental appearance, but also by reason of their non-liability to corrosion.

In concluding this brief explanation of the various advantages presented by M. Dodé's discoveries in metallurgy, it is only necessary to call attention to the various specimens exhibited this evening, and to state that, M. Dodé being present, it will afford him much pleasure to explain any matters of detail, or to answer any questions bearing upon practical applications of his inventions.

DISCUSSION.

The chairman, Dr. J. W. Russell, said he should like to know whether both processes mentioned, namely, the first one, by which the substance was covered with borate of lead, oxide of copper, and turpentine, and the other, in which borate of lead, oxide of lead, and essential oil of lavender were used, were necessary before the application of the tetrachloride of platinum.

Mr. Stoffel said the first process was applied simply when the iron was desired to be protected against oxidation, and the color was dark. If the second process was desired, its object was to coat the iron with enamel, which would give you two or three dark colors; it was principally devised so as to form a proper recipient for the coating of platinum. Without this process, the quantity of platinum required to cover the iron would be considerable, but when it was used, the quantity required was infinitesimal.

The Chairman said he understood that they did not platinize on the first process; but the second was employed when platinum was to be used afterwards.

Mr. Stoffel said that was so. They could apply platinum on the first process when a polished surface was not desired; but when a bright surface was required, you must use the second process.

M. Dodé, who spoke in French, gave a brief sketch of the experiments which had led him to develop this process. He had first sought to substitute platinum for mercury in the making of looking-glasses, of which he had made a considerable number, and specimens of which he exhibited. His factory being destroyed at the time of the war, he turned his attention to the coating of metals with platinum, and especially to avoiding that oxidation of the metal to be coated which took place in the galvanic process by the action of the acid on the surface before the deposition of the metal, the consequence of which was there was no solidity in the work. After many experiments, he succeeded in dissolving the platinum to the state which he showed in a small phial bottle, containing 7 grammes of platinum, and which he said was sufficient to platinize more than twice all the articles exhibited.

Mr. Spencer said he had heard of this invention within the last fortnight or three weeks, and having in earlier life tried to effect the same end, he felt a great interest in it. At first he was rather disposed to doubt, not that with essential oils a coating of platinum could be given many things, because he had already tried it, and it had been done with regard to china, producing the article formerly known as lüster ware, which was made at Tunstall in Staffordshire, a piece of which he produced. As far as he understood, it was applied in much the same way, but it had not been applied to metals. He had himself applied it to metals, but not in the same way as this. He applied it to lead, in order to get a negative galvanic plate to a battery, for which, many years ago, he took out a patent. When he heard of its being applied to iron in the same way which had been shown, he asked a friend who knew Mr. Stoffel to get him a bit of it, because he rather doubted whether it would stand. He had, however, put it to some very severe tests, and it stood in a way he did not expect. He must, however, say there were some few pin-holes of a trifling character; but he was convinced that a double coating would produce such a protection to iron as had never been seen yet. He said this, having made many experiments in early life upon the subject, in the introduction of electrotyping. It was then a problem with him to coat iron with copper electrically, and he had succeeded, but only to a certain extent. It was not done with facility, and the iron had to be prepared very carefully in the first instance. Even then it was never a thing which could be largely adopted in practice, because there was so much trouble in getting rid of rust in the first place, and then there was a want of adherence between the two metals. He was, therefore, delighted to see the problem solved so simply. But as he was informed the iron was subjected, after the iron had been coated, to a cherry red heat, which meant something like 800° or 850°, there were some metals which could not be subjected to that heat with impunity. He had been often struck with the great many affinities between iron and platinum. In the first instance, they were two weldable metals *par excellence*. He also found in making experiments that adherence took place between them at certain heats, and that when this was achieved it would remain. The color of these specimens was not the true platinum color, which showed him that the surface of the iron and platinum had amalgamated, because platinum and iron would form an alloy. No one probably would think of using platinum for looking-glasses if they could get silver or quicksilver, because the color was not so good. You might not notice it immediately, but a lady dressing for a ball would not like the cadaverous look it would impart to her countenance. It was now found that, by a new process, real silver could be deposited on glass by the aid of essential oils; but, in practice, it was very seldom they did not find defects here and there, where the essential oil had not been thoroughly removed. In fact, looking-glass makers told him that they could depend on nothing but the old mercurial process, which was not now open to the same objections as formerly. With regard to the covering of iron, it seemed to him one of the most valuable discoveries ever brought before the society: and, having had a great deal of experience, he must say he knew of nothing which came up to what he now saw. This process would do an immense deal for both the industrial and fine arts. He should hardly imagine that a vessel of wrought iron, if coated in that way, would stand the action of acid like a platinum vessel, but it would do an immense deal in other respects. He believed it would keep intact for ages as far as the influence of the atmosphere went, and, looking at the perfection now attained in iron casting, there was no reason why it should not be largely employed in artistic work. Some of the Berlin castings were as fine and beautiful as anything you could imagine in plaster of Paris; but the reason they were not used in public statues was that the iron was subject to rust, and when they were painted all their beauty was gone. By this process he could imagine almost every statue being made of iron instead of bronze, and it would not be subject even to the drawbacks to which bronze was in this country out of doors, being turned green, black, and other colors by oxidation. For statuary purposes two coatings might be given if necessary, and it might be done at once, before even the metal got cool from the castings.

Mr. Silk asked what was the cost of this process as compared with Mr. Barff's process, described the previous evening; what was the heat required for the inoxidation process; if the iron required any previous manipulation; and whether brass and other metals could be platinized.

Mr. Stoffel said he was not aware of Professor Barff's estimate, but the ordinary price of inoxidation was one farthing per square foot. That was the price actually arrived at on a small scale, and would most probably be diminished when working commercially. The treatment was regulated by the thickness of the iron. It had to be raised to a cherry red heat so that the oils might be evaporated and the pigments become melted and be embedded in the iron. According to the thickness of the iron so was the heat required, varying from 400° to 1,000°. The iron required no previous manipulation except to thoroughly dry it. The principal use of the first pigments was to prepare the surface to receive the platinum, but on polished steel or German metal the platinum might be applied direct, and would adhere with a less degree of heat.

Mr. Raper said any Englishman returning from abroad was generally struck with the peculiarly dull, unhandsome appearance of the buildings in comparison with what he had been accustomed to on the continent, and no doubt it had occurred to many that it would be most desirable if the inelegant appearance of our houses could be improved, all their conditions of stability and durability being preserved. He had no anticipation that this invention would supersede the galvanizing process for some purposes, but there were no doubt many applications for which the latter would not be suitable, and one of those would be to cover the outside of buildings generally with thin plates of iron coated with platinum, and in certain forms of decoration. It also might be adapted to the interior of rooms. The ornamental appearance of the glazed ware about the buildings of South Kensington and the Albert Hall might have struck many people. Encaustic tiles were capable of a large amount of beauty and immense solidity, but they were far too expensive for general adoption. There was a process, however, which might be adapted to many ornamental purposes of that character with great advantage. Such thin plates of iron might be stamped in any ornamental design or even color. He had always understood that metals were opaque, but he noticed that one sheet of glass which had been handed round coated with platinum could be seen through, showing that the coating must be exceedingly thin. The advantage of these thin plates of iron would be that they would not be breakable, and they would not affect any rain water passing over them. The idea of introducing platinum, one of the most expensive of metals, on such a wholesale scale as this, struck him as certainly a most daring iden, and reminded him of the old motto, *audaces fortuna juvat*.

Mr. Edward Spon said it appeared rather invidious to criticise an invention with such beautiful examples exhibited, and it certainly did not require much consideration to understand the value of any process by which platinum could be applied in extremely thin films impervious to acid and oxidation; and any man who could do it would realize a large fortune. He confessed a doubt whether this invention in its present stage would resist oxidation or acids. It was not at all a new thing that metals mixed in some form with essential oils would form a coating on other metals. Cooley's "Cyclopædia of Receipts" had about twelve or fourteen receipts for this operation, all of which he had tried, and they were all more or less defective. In one of them bichloride of platinum, or bichloride of gold, was dissolved in tannic acid, which produced very easily a coating of platinum on brass; but, as far as his observations went, it would not touch iron. He had been through M. Dodé's experiment, as far as he could on a laboratory scale, but could never get a bit of iron sufficiently coated to resist the action of the atmosphere. Mr. Spencer had spoken of pin-holes, and all his deposits had been streaked. The heat to which the articles were subjected would certainly seriously affect any small article of iron or steel. He could not see any description of the process in the paper, but, as far as he understood, the action of the essential oil was to precipitate the metal in a finely divided state; but the heat that the article was subjected to afterwards would certainly not fuse the platinum sufficiently to make a thin coating; and, if it was only thrown down in a powdered state, it must inevitably have interstices, however small, which would be open to the action of acids or oxygen. He also doubted whether M. Dodé would not find the expense considerably more than he anticipated, because nearly all the articles used were of a very expensive nature. Perhaps some other essential oil might be found to replace the oil of lavender; the oil of lavender, of the quality necessary to be used in the process, would cost in England at least £4 5s. to £5 per fluid ounce. The Continental oils of Spike, which were used to replace oil of lavender, were very cheap; viz., 3s. to 5s. per lb., but they were totally useless, and as far as he could ascertain, the ordinary English oil of lavender was also worthless. He should like to know if the operation of burnishing was required, because it was very expensive on platinum.

Dr. Lempriere regretted that it was not in his power to deal with this question from either a scientific or a commercial point of view. The only point to which he would address himself was the enormous advantage which would arise from this process to ordinary householders. Some observations had been made by Mr. Spon, but the answer was a simple one of fact; Mr. Spon had not succeeded, and M. Dodé had. With regard to the other question, about the streakiness and the spots, he looked upon it solely as a practical man of common sense. He had been present at almost all the experiments made by some of the best scientific men of England, some of them conducted at Messrs. Johnson, Matthey & Co.'s, in the presence of some 30 gentlemen, who were picked out as being of great eminence in connection with metallurgy. The experiments conducted in Mr. Matthey's office, before these gentlemen, did not show a single failure. Mr. Spencer—than whom there could be no greater authority on the question of metal-plating—had told them there might be certain small pin-holes, after subjecting these specimens to, perhaps, the severest chemical test known, but yet, by a second coating, all danger from these pin-holes could be obviated. There were many questions it would be presumption for him to touch upon, but he could not help remarking what an enormous advantage the application of such a simple and inexpensive process would be to common domestic

use. Every day iron was being used more and more for the utensils of the house; almost every part of our houses was being improved by a more easy and cheaper appliance of iron. The water-pipes which carried off the rainfall were a source of constant expense from the enormous oxidation that occurred, sometimes going so far that they actually rotted away at the ends; but if, by this process, they could be made, as Mr. Spencer had said, to last for ages, all that expense and annoyance would be prevented. That was with regard to the first process. Then, with regard to the second, he would remark that the first thing you touched in going into a railway carriage was the door-handle, which was made of brass, and very expensive; but, by M. Dode's process, it could be made of iron, which was much stronger, and, of course, it would look like silver, and serve equally as well.

Mr. Manning said one ounce of experience was worth a pound of theory. He had been to Paris to see the process carried out, and the stove now exhibited he saw in its original state of cast iron; it was coated by M. Dode in his presence, and put through the furnace and turned out in the condition in which it now appeared, having been twice in the furnace in the space of 12 minutes. As regards the cost, he was obliged to take the figures given him, but he was told that the difference in cost of platinizing and nickelizing was £3 4s. He saw there were some flaws in some of the articles, and the reason was explained in this way: that there was a certain amount of damp which had not been removed; all this could be avoided by thoroughly drying the iron in the first instance. There was no polishing whatever, it came out of the furnace exactly as it now appeared.

Mr. Daw remarked that it had been put forward that this process would supersede galvanizing, and if the complete process could be done cheaper than galvanizing no doubt it would, but he doubted whether the first process only would do so, even if it could be done at one-fourth the cost. If the inventor could give any further information as to the results of the first process on common iron it would be interesting.

Mr. Spon asked if the prices of nickeling, with which the cost of this had been compared, were the prices in London, Paris, or New York; because it was comparatively an expensive process in London and Paris as compared with New York, where there were upwards of 200 nickel platers, while he did not think there were more than three in London, and certainly not 20 in the kingdom. The stationers' shops were now full of nickel-plated pencil cases, the majority of which were imported from the United States, a great number of them having been sent to New York, nickeled and returned. Consequently the expense must be trifling there, or the price would not pay the expense of carriage to and fro and the high duty. There was no doubt in a year or two nickel plating would become as cheap in England as in America, and therefore the present prices would not form a basis for calculation.

Mr. Manning said he only took the prices given him, which no doubt were the Paris prices.

Mr. Raper said when he expressed an opinion that this process would not be likely to supersede galvanizing, he meant his remark to apply to the common and cheapest kind of galvanizing—the ordinary coating of iron with zinc, by an acid bath. He thought Mr. Spon was slightly mistaken as to the cost of essential oils, and that there were oils which would answer quite as well as the particular one named. If it would stand the heat, the first process might very well be applied to stoves instead of blacklead.

Mr. Spencer wished to make a remark on the theory of adhesion, and the action of the essential oils in this process. These oils consisted almost wholly of hydro-carbons. The doctrine was almost settled amongst chemists that hydrogen was a metal, and there was nothing so well suited for joining metals together as any body in which there was a large proportion of hydrogen. In 1840 he theorized on this principle, and put it into practice in what was called autogenous soldering; by which he brought two pieces of lead together without the intervention of solder, because previously a galvanic action was always set up at the point. He used a blow pipe with pure hydrogen, and fused the two metals together. He then asked himself the question how it was that one thing assisted the plumber's soldering and another did not, and in the *Mechanic's Magazine* for 1840 or 1841, he published a paper showing the different materials and substances which would induce soldering most, and it appeared that they were in the ratio of the hydrogen they contained. With regard to what was called galvanizing iron, or covering it with zinc, every one knew how rotten zinc became by the action of the atmosphere and the sun; it was slightly better than wrought iron, but even for covering buildings it was by no means so perfect as he thought this process would be. It struck him that there was one drawback about this process, namely that, if largely used, it would tend to increase the price of platinum.

Mr. Pearsall asked if there was any possibility that the process which took place in the furnace under the influence of heat would take place gradually by the action of time, if the preparation were applied in places where it would be impossible to heat it afterwards, as for instance in the interstices of wire rope. It was well known that many iron structures were in a dreadfully insecure condition, and it was very common for the police to give notice along the line of a procession that balconies should be avoided. It often happened that though they were constantly painted, the portion of the iron work which was embedded in the wall became quite rotten, and disintegration might also be going on to a great extent under a nicely painted external surface. He had been struck with awe on seeing the shameful state of the wire rope in a bridge over the Thames, where the oxide of iron had exfoliated in lumps like bunches of currants. That bridge had since been painted, and when he last inspected it he found that the paint had been put on over these masses of oxide. In such cases as this the invention now brought forward would be of immense importance, if the preparation were allowed to work its way into the interstices of the cable, and it would then protect the surface of the iron. When one metal was laid upon another there was almost always a galvanic action, so that in the case of a tinned saucepan, or galvanized iron, if the tin or zinc got knocked off, the metal underneath would be destroyed much more quickly than if it had never been protected.

The Chairman asked if any of these stoves had been used, because the point occurred to him that by changes of temperature the enamel might, to some extent, become detached from the iron; on the other hand, it might be so exceedingly thin that it would expand with the iron and not peel off. He always liked to see specimens not quite perfect, which had been somewhere so as to show the defects. Mr. Spencer had referred to the pin holes, and with a magnifying glass he could see them, though they seemed exceedingly small; but he should like to know if any specimens had been tested for any length of time in the atmosphere from the acid fumes. One other question of great importance to him as a chemist was, whether iron vessels could be coated with platinum by this process, so as to take the place of the very expensive vessels which were so useful in a laboratory.

Mr. Stoffel said they had a stove in use in Paris all the winter, burning coals or coke 16 or 12 hours a day, and it showed no difference in appearance from the one now exhibited. As the invention was a novelty, they could not give a longer experience. But they now turned out better work than at first, as would be seen by examining some of the small articles now shown. One ornamental casting in the room had been exposed to rain and frost all the winter, and other specimens had been exposed nearly a year, and had not shown any deterioration. The greatest precaution required was to see that the iron was thoroughly dry. The mineral composition, which was the essence of the invention, melted and went into the iron, closing the pores and giving a perfectly secure surface. On this the platinum, or gold, was deposited, and it was in this way that they were able to decorate articles as shown with an infinitesimal quantity of precious metal. It was found that it took about 20 times as much gold to gild a piece of iron in the ordinary manner as it did by this process, and it then only looked gilt, whereas by this method it looked like gold, and would wear 10 times as long. There was not 6d. worth of platinum on the stove. The cost really consisted in the manipulation and furnace operation. It did not matter what oils were used. Those made use of in treating the objects exhibited had cost at Paris 17 francs the kilogramme, or about 6s. 6d. per lb. There was no burnishing required if the second process was adopted. He would point to a panel for a balcony, platinized on both sides, which had not cost 2s. 6d., and would not cost so much in regularly appointed works for the purpose, and this was not much more than it would cost to give it three coats of paint. Platinum could be applied to the surface of bricks or porcelain by this same system, exactly as it was to glass, and it was anticipated that great use would be made of it for this purpose in order to reflect light in the city of London. The cost of this application to the surface of white brick would be, he expected, about 1d. per foot, and no atmospheric influence could injure it for a considerable period. With regard to vessels for holding acids, he could only answer as yet for small vessels. No acid would attack a coating of platinum, and if three or four coats were applied on well prepared iron, a substantial vessel could be prepared for containing acids, but it would require several coatings, and it must be done with great care. Several very stringent tests of durability were made at Messrs. Johnson & Matthey's laboratory. Pieces of iron brought from the Carron Company were treated on the spot, and were then subjected to the action of hot steam for 48 hours, and never varied. Afterwards, they were subjected to the action of acids and alkalies in a sand bath for 48 hours, and did not vary. Upon that, a very favorable opinion was expressed as to the importance of the invention, and it was stated at the same time that, if they had it in use in the North of England, where alkali and bleaching works destroyed iron roofs to such an extent that they had to be renewed every three years, it would be of immense service. In some respects, cost was a secondary consideration; but they had settled beyond doubt that the cost of the inoxidation process was less than that of galvanizing. The high prices and the scarcity of platinum had been mentioned as drawbacks to the general use; but eminent mineralogists have expressed the opinion that the supply obtainable from Russia alone would be amply sufficient for a far greater demand than that at present existing, and that large unworked deposits of it are to be found in other localities. By M. Dode's process, crude platinum can be made use of, and the costly operation of refining the ore, and getting rid of its alloys of osmium and palladium, which so greatly enhances the price of the purified metal, is entirely dispensed with. The infinitesimal quantity needed to coat a large surface must also be taken into consideration. The method of applying platinum to the surface of ceramic substances, mentioned by Professor Spencer, was actually discovered by M. Dode's grandfather; and after being carried out by him in Germany at least 70 years ago, was subsequently introduced into England, and practiced at Tunstall, in the production of what is known as "luster ware."

The Chairman said it was somewhat remarkable that two processes, which would, no doubt, prove of great importance in the future, each devised for the purpose of making iron a permanent metal, had been developed in that room on successive evenings. He did not wish to express any opinion as to the relative merits of the two, but he believed that each had a great future before it; the appearance of the iron after undergoing the coating was very different, and time and experience would show under what circumstances one process or the other might be used with most advantage. He concluded by moving a vote of thanks to M. Dode and Mr. Stoffel.

The resolution was carried unanimously, and the meeting adjourned.

SLATE QUARRIES OF MONSON, MAINE.

[Boston Journal of Commerce.]

THE town of Monson, where the above-mentioned slate quarries are located, is situated in the western part of Piscataquis County, about eighty miles northwesterly of Bangor, and fourteen miles south of Moosehead Lake. The town is most conveniently reached by way of the Bangor and Piscataquis branch of the E. & N. A. R. R., stopping at Abbot Station, which is five and a half miles from the village of Monson.

Slate was first discovered at Monson in July, 1870, by Wm. G. Williams and John C. Tripp, then residents of Brownville; and the following August the first blow was struck on that part of the slate vein now known as the Eureka quarry, by Wm. G. Jones. Here was commenced the manufacture of slate the following September. Such was the quality of the slate obtained, near the surface, and at so small an outlay comparatively, that parties were induced to see what could be done at other points on the vein; and accordingly, in April, 1871, Dr. L. E. Norris commenced operations on a portion of the vein purchased of Rev. D. P. Bailey, and now known as the Eastern quarry. In May, 1871, what is now known as the Hebron Pond quarry was opened by A. Chapin and others. In May, 1872, the Cove quarry was opened; and in May, 1873, work was commenced on what is now known as the Dirigo slate quarry. The several quarries now constituting the slate operations at Monson have had an eventful history, each having been worked, more or less, experimentally and under great disadvantages, with lack of proper machinery, etc.; yet the slate taken out in the meantime had acquired an enviable reputation. Some of the original owners of the quarries have disposed of their interests, while others were compelled to abandon any further working of them on account of the lack of capital. The comparative remoteness, too, of the slate from ready and convenient means of taking it out of the country to market also tended to depress and discourage the efforts of those who originally opened the quarries. The opening of the Bangor and Piscataquis Railroad to Abbot has, however, overcome that difficulty, and brought these slates into market.

EXTENT OF THE MONSON SLATE VEINS.

The width of the slate veins is about two hundred and fifty feet, and over a mile in length, and run east and west, beginning at Hebron Pond and terminating at Monson Pond. This immense body of slate lies in the village, being only ten minutes' walk from the hotel. The number of quarries opened is eight, as follows, respectively, beginning from the Cove quarry, organized in 1873; Hebron Pond, organized in 1872; Dirigo, organized in 1873; Eastern, 1873; Imperial, 1874; Eureka, 1871. The Forest and Oakland quarries were opened at a later period, and the latter one promises to be a great bonanza in its way. It is probable that it will eventually be united with the Forest quarry, and both worked under a single supervision, the pits at the present time being only a few hundred feet apart. Good slate was made from the surface of the Cove quarry, but deep operations were abandoned on account of the influx of water from the pond in close proximity. Work on the Imperial and Eureka quarries has been suspended on account of the lack of capital. All the slate companies referred to were incorporated either by special act or under the general law of the State.

QUALITY OF THE MONSON SLATES.

The quality of the roofing slates manufactured at the Monson quarries speaks for itself. It not only has the reputation of being the strongest slate in the world, but possesses a degree of elasticity that is really wonderful, considering the nature of the component elements of slate. It is of a blue black shade, and grows richer in color the longer it is laid, and withstands the changes of climate in a remarkable degree. It is of unfading quality. Respecting its strength, it has been tested over and over again by experts and others, by placing the ends of a large plate upon supports and subjecting it to a pressure equal to the weight of a man of 180 or 225 pounds upon the center without breaking it. But very few slates are capable of sustaining such a pressure.

SOME STRIKING PECULIARITIES.

Owing to the vein running in nearly a straight line the whole length, not varying more than four degrees therefrom, the slate naturally splits in conformity with the run of the vein, and in thickness each slate is as true as a sheet of window glass, having none of that curvature which characterizes most slates, domestic or foreign; and, as already noted, it has an unfading quality, which can scarcely be said of other slates, while its uniformity of tone and color are peculiarities worthy of special notice. The Monson slate, too, splits only in one direction, and consequently possesses much more inherent strength than do those slates that split in various directions, and is consequently stronger than any other slate known. Beautiful specimens of *dendrites*, resembling frost work, shrubs or trees, are sometimes found in these quarries on the "flint."

DISTINGUISHING FEATURES.

The best slates are distinguished by an appearance of compactness and solidity in their blocks, with nothing to suggest their fissile character; and yet this should be so perfect that, when fresh from the quarry, these blocks may be split with greater ease than pine wood, and into sheets of any desired thickness. This essential necessity is fully met by the slate quarried at Monson, the faces of the slate there being perfectly smooth and parallel, without any curvature or irregularities or blemish of any kind whatever. We speak of what we know from actual observation in this respect. When one of these Monson slates is balanced on the finger and struck with a hammer, it gives a clear ringing sound that does the ear of a man good who is in quest of the best slate. An excellent test of the comparative qualities or values of different slates is arrived at by adopting the procedure above noted, and also by drying the slate in an oven and then immersing it in water. If it is a superior article it will absorb but little water, as may be ascertained by weighing it before and after immersion. The quality of the slate taken from the Monson quarries is apparently one and the same, and all is easily worked. The absence of pyrites and the unsightly stains of oxide of iron from the Monson slate is a matter of comment by those who have visited the quarries.

THE PURENESS OF THE VEIN.

Those who have investigated the subject say that the slate vein at Monson, all things considered, is the purest yet known. The condition of the Oakland pit is a striking illustration of this view of the subject. This quarry was opened only last October, swampy land lying over what now presents a deep pit of the finest slate in the world, existing in wide veins, and free from extraneous matter. When the pits on the line above, where the land is more elevated, shall have been sunk to a depth on a level with the Oakland quarries, there is no doubt but that the seven other ones will prove as rich and clean in slate wealth. Respecting the "flint," it seems to surround the slate for a purpose just as the loaf of bread is preserved by its enveloping crust. "Flint" appears invariably on both sides of the slate, and both have the same angle.

COMPARED WITH OTHER QUARRIES,

those at Monson possess special advantages which conduce to a superiority of the slate manufactured. In these quarries the seams or joints, in which the slate is deposited, render the labor of quarrying comparatively easy. A man with a crowbar can quarry all day long, removing intact the regular chunks of slate from their walls—blocks of slate which lie in most instances as regular as though placed there by the hand of some master mason. The greater the width of the distance from the joints the greater the quantity of slate can be got out; otherwise it would be necessary to start a large mass of the material by explosive power, and consequently more or less waste would result. The difference between the "flint" of the Eastern quarries and those of Pennsylvania is marked, that of the former being very hard, and that of the latter soft, which is used to a considerable extent for flagstone. The Pennsylvania drift also lies differently, and varies in different localities, it being necessary to "lift" the veins of slate, while those at Monson are more or less in sight from the surface, and are easily got at. The Oakland quarry is also a good illustration of this peculiarity. After taking off about four feet of earth, which

consisted of a rich vegetable loam, with a heavy gravel under it intermixed with clay, level bed-rock was struck which exposed the veins of slate, and the intermediate, narrow seams of flint, the former presenting in some instances a surface of from nine to twelve feet in width of pure slate of unknown depth.

OPERATIONS AT A PIT.

During the visit of the writer to the Monson slate vein he visited the bottom of the Hebron Pond quarry. The pit, with its series of "benches" or shelves, is now about 250 feet long, 60 feet wide, and fully 100 feet deep. A dozen hatless men were at work in the depths, quarrying with crowbars, removing large blocks of solid, clear slate, or disposing of "rubbish." The mechanical appliances for drawing up the slate, "flint" rock, and rubbish from the pits are the same in general construction all along the line of the vein, consisting of two derricks at the principal quarries, properly supplied with steel wire ropes and blocks, the motive power being engines of adequate capacity, which also run all the other machinery used in trimming the plates of slate. Boxes of about the capacity of a common tip cart for carrying earth are employed in bringing up the material from the pits, and these boxes, loaded either with slate or debris, are swung into position wherever wanted, and their upward or downward movement is regulated by a brake attachment. So the heavy and cumbersome loads from the pits are handled with comparative ease, all the slate being put on to a flat car and rolled into the sheds where the slates are manufactured, and the "flint" placed on similar cars and moved on a similar tramway to the dumping grounds. Some of the Welsh slate quarries are 300 feet in depth, and contain less rubbish, perhaps, than most of the American slate quarries; but after the surface stuff of any slate vein is removed the quality of foreign matter grows less and less in proportion to the depth of the pit. The Oakland quarry of the Monson vein, for instance, is at the present time as clear from rubbish as the finest dry dock of any navy yard in the country. All the other quarries here will also be as clean in time, and consequently it will require less effort to work them, and the more they are worked the more advantageous will they become to those directly concerned.

DOWN IN THE DEPTHS.

We gratified our curiosity to tread the bottom of one of those slate pits by stepping into one of the boxes above described. In less than a quarter of a minute we stood upon a mass of unquarried slate. The sensation experienced during our rapid transit from the surface of the earth down into the bowels of the slate quarry were peculiarly undefinable. We have been up in a balloon, fell overboard, been kicked by a mule, and hoisted by a steamboat explosion, but it is the rapid going down process, the stop in the descent with a jerk, to find yourself for a time a prisoner inside of four perpendicular walls of stone, that combine to render a trip of this kind sensational almost before it has been experienced; but we had faith in the strength of that steel-wire rope by which we were suspended between heaven and earth for the time being; and when we made the ascent and found mother-earth under our feet again, we thought of the family we had left at home, and then shuddered at "what might have been" if that rope had parted—and no insurance on our life, either.

HOW THE QUARRYING IS CONDUCTED.

Every slate quarry has a superintendent, and every gang of men has a head, or ledge-man, whose business it is to see that the work of quarrying is conducted advantageously. It requires a practiced eye to detect at a glance the slate and the flint; and of all men engaged in the business, the Welshman, who has worked in the slate quarries of his own native Wales, can most readily read as it were the language of rocks. He knows what every seam means, and what it will lead to, and its geological relations. He knows just where the "flint" begins, where it joins the slate, and fully understands the faults of the slate veins themselves. What he cannot accomplish with his simple crowbar he will effect by the use of an explosive, exposing large masses or blocks of the finest slate the world ever saw. These he loads into the box, whereupon he cries "slate!" and in less than an hour the material is transformed into plates to cover, perhaps, the roof of a public building hundreds of miles away in a distant State. Many of the workmen employed in the Monson works are Welshmen whose experience in the slate business has been acquired in the famous quarries of Great Britain, from childhood as it were, and whose fathers were engaged in the same business before them. With such intelligent workers, and proper machinery for manipulating the slate, it is not to be wondered at that the demand for the article has been so great that the general agents, Clement, Higbee & Co., have orders far in advance of their supply.

SPLITTING AND TRIMMING.

Not the least interesting feature in the manufacture of roofing slates is the splitting and trimming processes. The large pieces of slaty rock brought up from the depths are sometimes regular and sometimes irregular in form, and of various thicknesses. Those not familiar with the process of making roofing slates, may have had an idea that the article was made by a process somewhat similar to making shingles, by shaving or sawing them. The slate in bulk is run into the cutting and trimming sheds, as already intimated, where it is taken in hand by the workmen, whose great familiarity with the material enables them to decide at a glance how it can be manipulated. A wide, thin chisel in used in splitting the slate into different thicknesses, and the ease, rapidity, and uniform perfection with which the slate in the form of plates is cleaved off is quite wonderful to behold, while the thoughts suggested to the observing mind by this simple process, lead one to speculate as to the number of million years that very slate has been lying embedded in the earth, now brought to the surface and split into uniform parts, and exposed to the influence of the air and the sunshine to harden for a practical purpose in this year of our Lord 1878. Really, all physical phenomena are surveyed through the glasses of the past.

DESIRED SIZES OF SLATES.

There have been improvements in the trimming of roofing slates as in every other department of industrial pursuit. In the early days of its manufacture, the slates were trimmed by hand, resulting in more or less variation of size, which it made impossible to lay a roof with the article with any degree of neatness or guarantee against leakage. The means employed by Clement, Higbee & Co. in producing roofing slates of exact uniformity in size, as well as in thickness, are complete and unerring in their character, so that when the slates are piled up they present all the uniformity of size that so much window glass would. The best of workmen are employed in this respect, and the trimming is all done by a knife which is operated by steam power, the operator reducing the slates to the size to which they will work to the best advantage, no imperfect ones being allowed to go from the quarries. The sizes manufactured at the Monson quarries range from 24 by 14 to 10 by 6, including some thirty-four different dimensions. The largest sizes are in demand for extensive public buildings.

VARIOUS INTERESTING ITEMS.

The number of men at present employed on the slate line at Monson is about 125, and this force will soon be increased, on account of the growing demand for the product. Considering the times and the low prices, the men employed here are well paid and have steady employment.

The Hebron pit has produced since January 1 (to Aug. 31) some 3,500 "squares" of slate. The men employed in splitting and trimming the slates work on contract, receiving a certain sum per "square" (which is ten square feet. The same men who split also trim to the measure. This system is also in vogue at all slate quarries, and it has been the practice in Wales for the past three hundred years. It is probable that the product of the Monson quarries, during the next six months will equal 15,000 "squares" of the best slate in the world.

UTILIZATION OF WASTE MATERIAL.

The "flint" that is now thrown aside as rubbish, in the quarrying operations at Monson, is well adapted to several practical uses. For flagstones, street crossings, and doorsteps, it would serve admirably, being very tough yet easily worked into any desired shape. The flint of the Pennsylvania quarries is utilized in this way, particularly in the cities of Philadelphia and Baltimore, and other large places within a reasonable distance of the slate quarries.

Were the Monson quarries located within one hundred miles of Boston, their "flint" rock would become very popular for the purposes mentioned, as it could be afforded at a low price, supplanting, perhaps, some kinds of stone now in general use which are less serviceable in their character.

SLATE COMING INTO MORE GENERAL USE.

We in this country do not use slate for roofing purposes so generally as is the case in Great Britain and other foreign countries, but we notice that of late years the article has come into favor in all our large cities and towns. Pratically, in the long run, slates are more economical than shingles for roofing purposes, because the latter have to be renewed, while the former will last as long as the roof that holds them. The difference in the cost of slates and shingles is not as wide apart as it used to be, the prices now almost touching each other. It is one of the compensations of Providence or nature, that, while the belts of pine and spruce timber in the United States and in other timber-producing countries are producing less and less material for lumber with each successive year, the discovery and quarrying of slate almost keeps pace with the growing scarcity and increasing prices of shingles; and no doubt the day is not far distant when slate will be used as extensively for roofing purposes as is now the case with shingles. The economy gained by the use of slate comprises a wide scope. The material is a preventive against fire, thus finding favor with insurance companies; slates look neater on a roof than shingles, and a slated house is more attractive and will sell quicker and for more money than a shingled house. Respecting the

SUPPLY OF MONSON SLATE,

the vein is inexhaustible, and slate like that found in these quarries has not yet been equaled. A good roofing slate is so rare that the Monson slate, with its peculiarities, is a matter of great commercial importance. This slate must always be in demand. It is packed away in the immense vein for a utilitarian purpose—to meet the coming demand for slate for roofing purposes. The cost of quarrying it is comparatively slight. In view of the actual scarcity of good slate, the product of the Monson quarries is destined to be much sought for.

FOREIGN ROOFING SLATES.

The rocks which yield the best roofing slates are no doubt the Cambrian and Silurian, although some is obtained from the Devonian and Old Red Sandstone. The most extensive slate quarries in the British Islands are those of Penrhyn, Llanberris, and Festiniog, in North Wales. In this district about 350,000 tons of slate are annually produced. At Barrowdale, in Cumberland, and at Easdale and Ballahulish, in Argyleshire, there are also large slate quarries, as well as lesser ones about Dunkeld and many other localities. Until within a few years large quantities of Welsh slate were imported into the United States; but since the development of the American slates scarcely any Welsh slate is imported, and

THERE IS A LARGE FOREIGN DEMAND FOR THE AMERICAN PRODUCT.

For roofing purposes the Scotch slates are stronger but coarser-looking than the Welsh, while the American Monson slate is superior to either for roofing purposes. It was the custom for ships returning from Liverpool, after carrying there a load of cotton, to often stop at Bangor, Wales, for a load of slate from the quarries in its vicinity. But now a change has come in the slate business. Instead of ships bringing slate from Bangor, Wales, the article is now exported from Bangor, Me., U. S. A., either in vessels or by railroad. The coincidence of this, so far as the name of the port is concerned, is remarkable, to say the least. The Welsh quarries which were opened toward the end of the last century by Lord Penrhyn, and which now give employment to as many as two thousand persons, and produce an enormous annual revenue, are destined, sooner or later, to find a sturdy rival in the Monson quarries; for we hear that inquiries for the Monson slate have already been made by parties in England and France, who, having detected the superior quality and fine, lasting luster of this slate, are anxious to get it for buildings, both public and private.

THE VINO-COLORIMETER.

IN order to determine the coloring power of wines, a matter which in France has considerable influence on their market value, various apparatus have been proposed bearing the general name of *colorimeters;* none of these, however, have as yet attained the end in view and answered the needs of commerce. The solution of the problem, indeed, presents some difficulties; all wines do not possess the same color, some being red, others more or less violet, and the same wine in acquiring age assumes a yellowish tint called "onion peel." How, then, are colors so unlike to be compared? If all wines are not of the same shade of color, and it is impossible to determine the depth of the latter, then it is absolutely necessary that a scale of all the tints that red wines assume should be created. This is precisely what all inventors of colorimeters have hitherto neglected to do. Such a scale would serve at the same time as an index to the names of the colors of all wines, thus allowing, for instance, a wine-grower to write to a dealer:

"My wine of this year's vintage is of such or such a number of the red scale, and its depth of color is represented by such or such a number."

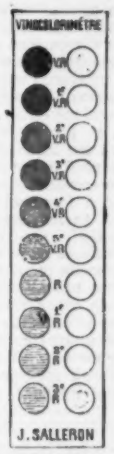


FIG. 1.—THE TEST SCALE.

The dealer, knowing the precise color demanded by his trade, would thus be better able to judge of the value of the liquor offered him. Is it possible, in the present state of science, to catalogue the different colors of wine? This question, M. Salleron, the inventor of a new and ingenious *vino-colorimeter,* answers in the affirmative.

M. Chevreul has not only published a "Method of Defining and Naming Colors," but he has also reproduced and

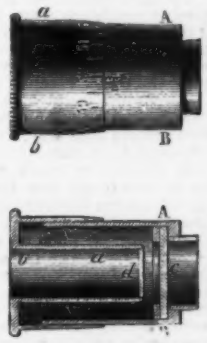


FIG. 2 AND 3.

classified them. This classification, which may be seen at the carpet manufactory of Gobelins, contains every shade of color that art can be called upon to reproduce. By comparing with this the tints of the different varieties of red wines, M. Salleron has ascertained that the wines called *blue* (principally from the banks of the Loire) do not reach the scale of colors called by M. Chevreul *violet-red;* and that old

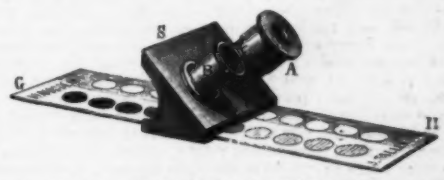


FIG. 4.—THE VINO-COLORIMETER.

stale wines that have lost their commercial value do not get beyond the 3*d red.* Between these two colors, *violet-red* and the 3*d red,* there are at the Gobelin's ten intermediate scales that M. Chevreul names thus:

Violet-red—1st violet-red, 2d do., 3d do., 4th do., 5th do.

Red—1st red, 2d do., 3d do.

These ten colors and their present designations form a true

FIG. 5.—METHOD OF USING A VINO-COLORIMETER, PROVIDED WITH A CONICAL SCREEN.

vino-colorimetric scale, which is made use of by M. Salleron, not only to denominate all the colors of wines, but also to determine the intensity of the same. His apparatus (Fig. 4) is as follows:

A series of disks of satin ribbon, dyed exactly according to the types at the Gobelins, and each of which represents one

of the numbers of the scale above cited, is glued to a strip of card-board one above the other (Fig 1), from violet-red to the 3d red. Alongside of these is glued another series of disks, each made of pure white satin. This is the test-scale. Accompanying this is a small spy-glass (Figs. 2 and 3) composed of a silvered-copper cup, A B, with a glass bottom, *e*, into which enters a tube, *a b*, of the same metal, also closed at the bottom by a glass disk, *d*. The separation of the two glasses is varied by means of a screw, so that on pouring wine into the exterior cylinder the thickness of the vinous layer between the two glasses varies likewise. In a word, this little apparatus is only a modification of the old colorimeter of Payen, but its dimensions are much smaller, and the addition of the micrometer screw allows the thickness of the layer of wine to be measured with great accuracy. This colorimeter is fixed to a small support, S (Fig. 4), inclined at an angle of 45°. A second spy-glass like B, but having the glass disks stationary, is placed on the same support and alongside of the first, at the same distance apart as one's eyes. The apparatus is used in the following manner:

Into the cylinder with movable glasses (which is the colorimeter proper) is poured a few cubic centimeters of wine. The apparatus is fixed to its support, and beneath this is slid the colored scale, G H. One of the red disks will be found opposite the cylinder with fixed glasses, and one of the white satin disks opposite the colorimeter, A, so that in looking through the two tubes at the same time, there will be seen alongside of each other two colored disks, one of which will be one of the tones of the scale, and the other a red tone formed by the vinous layer coloring the disk of white satin. By sliding the scale along until the color of the wine exactly coincides with the color of one of the disks of the former, the shade and its depth are at once determined.

A COLLECTION OF THE OLD MASTERS IN PERU.

Le Temps contains the following curious letter, which gives an account of a remarkable collection of the old masters at Lima: "Who would believe that Lima, which has no museum of the fine arts, has, nevertheless, a private collection by the side of which many an European gallery would be colorless—a collection of more than eleven hundred paintings, the greater part of them signed by the noblest names of the Spanish, Italian, Flemish, Dutch, and French schools? Yet there is nothing more true than the existence of this extraordinary collection; the proof is that I have seen it, and this is what I saw: In one of the oldest houses in the city there lives a hospitable gentleman, Don Manuel Zaballos. Whoever knocks at the door of his house is well received; but I ought to say that generally none but strangers ever present themselves. The Peruvians seem to be ignorant of the Collection Zaballos, doubtless because they have none too much time to admire their female compatriots. In the first room are a hundred small Spanish and Italian paintings, perfect gems in their way. The master shows us, with a certain off-handedness, three admirable Murillos, and, although we are inclined to speak more at length of this Magdalen, this St. John, and this Descent from the Cross, he leads us into his Salon Carré and confronts us with a Zurbaran well known to, or at least much sought after by, connoisseurs—the Ecstasy of St. Francis; on the right are two superb Rubens, on the left a Van Dyck; on every side hang haphazard, in tarnished and worm-eaten frames, Raphaels, Claude Lorraines, and Paul Potters. In the next room is the same profusion of chefs-d'œuvre in the same disorder; the schools are a perfect jumble; the subjects injure one another; here and there the frames overlap; but still here are the names of the same great artists. Before these canvases, blackened, smoke-discolored, ill-arranged, our doubts vanish; our feelings of astonishment and admiration are better guarantees of the authenticity of the signatures than the signatures themselves. Finally we enter a gallery where there are perhaps fifty paintings; the middle and the two ends are occupied by three paintings, three chefs-d'œuvre—the Communion of St. Jerome—'But,' you will say,' you are poking fun at us, my fine fellow; the Communion of St. Jerome by Domenichino is in the Vatican: every one has seen it there, every one can still see it there. Because you are in Peru you think you can tell us fine'—Pardon, in my turn; I am very sorry for the Vatican, since the Communion of St. Jerome which is there is only a copy of the original, which is here. Do you wish a proof of what I affirm? Look at the Death of St. Jerome, at the other end of the gallery, by the same Domenichino, which has never been copied, as far as I know, and you will agree that it is difficult to be deceived when you have before your eyes two St. Jeromes in the same tone and almost in the same attitude. Let us move on. Here again is the first of Raphael's virgins; here is a battle piece by Salvator Rosa, as fine as that in the Louvre; three (life-size) equestrian portraits by Velasquez; some Tinttoretos, at least as fine as those in the Ducal Palace at Venice. Next is a complete collection of the Flemish School, with Teniers, Van Ostades, Gerard Dows enough to excite the envy of the Museum at the Hague; there are, besides, three Rembrandts. Whoever would study the Spanish school, too little known, would do well to come here to study it. He would see here a Cano, that Spanish Michael Angelo, representing the Birth of Christ, where each figure is a complete picture in itself. There is not a great name which is not represented by two or three canvases, not a picture which is not full of life, movement, passion. In short, we leave this house wonder-stricken, enchanted with our discovery, and envious of Don Manuel's good fortune in being able to study these masterpieces at all hours. But before we leave him, he surprises us once more. Taking from an old Louis XIII. bureau a sheet of yellow paper, he says, 'I am always grateful to the strangers who come to see my paintings, but I only preserve the names of those of my fellow-citizens who visit me. Here is a list begun six years ago, and see, there are not yet fifty names!'"

LUMINOUS DIALS.—M. Recordon, a Parisian clock manufacturer, makes known the fact that for two years he has constructed watches and clocks with luminous faces on a plan, patented by him, which does not involve the use of phosphorescent substances. It consists in passing an electric discharge through a Geissler tube filled with a gas which yields a bright light. For watches, the battery, one of Trouvé's thimble forms, is, together with a small induction coil, hung at the watch chain. Pressing a spring completes the circuit and illuminates the dial.

FLAME LIGHTNING.—A flash of lightning resembling a colossal candle flame, based on the horizon and surrounded by a fainter aureole, was recently observed in the province of Rio Janeiro, Brazil.

WRITER'S CRAMP AND ALLIED AFFECTIONS.

By GEORGE M. BEARD, M.D., New York.*

DURING the past few years I have been specially investigating the disease known as writer's cramp and affections allied to it, as telegrapher's cramp, musician's cramp, and the cramp of sewing-women, and others engaged in occupations that draw so severely and exclusively on certain muscles as to induce weakness of those muscles and of the nerves that supply them.

These investigations have been pursued in various ways—by the study of cases in my practice; by conversation and correspondence with physicians from all parts of the country and other countries; by consultation with physicians in regard to cases, and by circulars of inquiry that have been noticed in various journals and brought to the attention both of physicians and the sufferers from the disease. The inquiry has extended to England, Germany, and Australia.

The conclusions at which I have arrived, stated in the most condensed manner possible, are as follows. I present the results without argument or discussion, reserving the details for a subsequent occasion, and shall here confine myself to those facts that are more or less novel and unfamiliar, and of the greatest scientific and practical interest.

The main results can be stated in these eight propositions:

First.—What is called the cramp is but one of a large number of the symptoms of this disease, and no two cases are precisely alike.

There are at least fifteen or twenty other symptoms of this disease. The recognition of these symptoms, especially in the early and premonitory stage, is of the highest moment, for the reason that in the early stage the disease is curable.

The cramp in those cases, where it appears, is oftentimes one of the later symptoms, and bears much the same relation to the disease that the symptoms of the ataxia gait bears to the disease locomotor ataxy. In some cases there is no cramp from first to last, and in all cases the cramp is preceded or accompanied by other symptoms.

The list of symptoms of writer's cramp is as follows: 1, fatigue, exhaustion; 2, dull, aching pain; 3, nervous, irritable feeling; general nervousness; 4, trembling, unsteadiness; 5, cramp, spasm, jumping, twitching, rigidity, contraction of muscles (in some cases the pen is involuntarily hurled at a great distance, as across the room); 6, stiffness and tightness; 7, powerlessnes, helplessness; 8, numbness, areas of anæsthesia, tingling; 9, neuralgia; 10, burning, stinging, dancing, prickly feeling; 11, soreness; 12, throbbing and swelling feeling; 13, thrilling, running, electric sensations; 14, tightly-bound feeling of wrist; 15, coldness; 16, abnormal sensitiveness to touch or cold, or mental influences; 17, disinclination to write; 18, slowness in writing; 19, itching; 20, perspiration; 21, temporary aphasia; 22, dryness of the joints; 23, swelling of the wrist and hand; 24, actual paralysis; 25, abnormal grasp of the fingers on the pen-holder or pencil—a very common symptom; tendency of the fingers, especially the middle one, to slip out of their places on the pen-holder, creating a desire by the sufferer to moisten them to prevent slipping; bearing down on the paper with unnatural or unusual pressure.

Many of the above symptoms are not confined to the hand, but extend to the forearm, arm, shoulder, neck, to the opposite arm, and over the whole body. It is clear, therefore, that the term writer's cramp is the worst possible misnomer, and that the disease has been most imperfectly understood in medical literature. It is wise, however, to retain the term both in scientific and popular circles, for in the prospective state of our knowledge no term capable of including precisely and exhaustively all the phenomena of the disease can be suggested. When any disease is designated by a term that is at once short, familiar, and easily retained, it is not well, as a rule, to attempt to displace it. To name diseases from prominent and special symptoms, and real or suspected factors in their causation is, during certain stages of medical progress, both natural and inevitable, as is illustrated by hay-fever, epilepsy, hysteria, insanity, neuralgia; and to attempt to substitute terms based on imperfect and changing knowledge of pathology, is to heighten the confusion that we would remove.

Secondly.—Also in the other forms of professional cramp, as that of telegraphers, musicians (violinists, organists, pianists, harpists), sewing-women, painters, artists, dancers, hammer-palsy, and so forth, the cramp is but one of a number of symptoms, and by no means always the most important symptom; and, as in writer's cramp, there is frequently no cramp at all from the beginning to the end of the disease.

There is no one symptom of the disease that can be said to be diagnostic. It is by taking a survey of all these symptoms, and by studying them in their relation to each other and to the history of the case, that we are able to make out the diagnosis of writer's cramp, or any of those allied disorders. This rule applies to the entire nervous system; there is not a disease known to neurology that can always be diagnosticated by any single symptom; all the familiar disorders of the brain, of the spinal cord, or of the peripheral nerves are studied not through isolated phenomena, but through groups of phenomena, acting and reacting on each other; pathognomonic symptoms belong to lecture-rooms and text-books, not to practical experience.† An analogous disease, that has not been described, is the counting-money cramp, from which a lady-clerk in the Treasury Department at Washington once suffered; it is caused by excessive and restricted use of the fingers in handling bills.

Thirdly.—This disease is primarily a peripheral and local disease of the nerves and muscles; secondarily and rarely it becomes central and general, or it may result from various central lesions; and it may affect any point between the extreme periphery and the center.

This view of the pathology is a compromise between the old view that it was central, and the theory of Poore, of London, that it is purely peripheral.

No two cases are precisely alike in their pathology, but there is no question that in some exceptional cases the disease extends to the centers. That it affects the left hand as well as the right is no proof that the disease is central; it simply develops to the left hand when that hand is used, for the same reason that it affects the right hand.

The theory that writer's cramp is a result of lesion or disturbance of special co-ordinating centers in the brain is not sustained by a single properly-understood fact; on every point it fails to account for and harmonize the phenomena. So far, my own conclusions are in entire accord with those of Dr. Poore, of London, who has investigated this subject most intelligently and successfully.*

In truth, the detailed pathology of writer's cramp is not simple but complex; in some cases there is neuritis which may affect a single nerve branch or several nerve branches, and may be restricted to the fingers and hand, or extend up the forearm and arm; then the muscles may be merely exhausted—chronically fatigued—or with a tendency to spasm and contracture. The worst phase of the disease that I ever saw was in 1874, with Dr. Brodie, of Detroit; in that case the arm was drawn over to the back, and held firmly there by the contracted muscles; the patient was unable to use his hand for any purpose, and also suffered great pain.

In some cases the disease, or rather the tendency to the disease, is hereditary—two or three cases having been known in a single family.

Fourthly.—This disease occurs mostly in those who are of strong, frequently of very strong, constitutions, and it is quite rare in the nervous and delicate; and when it does occur in those who are nervous, is easier relieved and cured than when it occurs in the strong.

This fact is not peculiar to writer's cramp, but applies to other nervous diseases, as impotence, muscular atrophy, and ataxy. I see every day cases of nervous exhaustion (neurasthenia) in its various forms, and quite rarely do I see writer's cramp in them; and when they do have this disease, it is mild and curable. I have successfully treated a number of these cases.

Fifthly.—This disease is far less likely to occur in those who do original work, as authors, journalists, composers, than in those who do routine work, as clerks, book-keepers, copyists, agents, and so forth.

The reason is clear. Original thinkers must take time for thinking as they write, and thus they rest the nerves and muscles of the hand; while routinists, having little or no thinking to do, write on constantly and uninterruptedly, oftentimes at the extreme of their speed.

In some cases an attack of writer's cramp has followed a single task of long copying. In one of my cases—an authoress—there never had been any sign of the disease until she performed a task of routine work. Of my cases eight were physicians, eight were lawyers, five were clergymen, and the remainder were clerks, book-keepers, agents, copyists, and merchants.

Men who write bad, scrawly, illegible hands never have writer's cramp; it is the penalty for writing plainly and carefully. Like prevents like, and those who always write as though they had writer's cramp never have it.

Sixthly.—This disease, like all nervous diseases in this country, diminishes in frequency as we go South.

In the Gulf States writer's cramp and maladies allied to it are very rare. The same is true of hay-fever, which is a type of nervous diseases, and, indeed of the whole family of functional nervous maladies, such as sick-headache and neurasthenia, or nervous exhaustion in all its manifestations.

In investigating this subject I have corresponded and conferred with physicians all through the South. Dr. Bryce, Superintendent of the Alabama Insane Asylum, Tuscaloosa, whose opportunities for observations have been very large, has written me a very interesting letter on this question.

Seventhly.—Writer's cramp is no longer an incurable disease.

In the early and forming stage, especially, it responds to treatment quickly, and in many cases permanently. During the stage of exhaustion, fatigue, and pain, with the other symptoms of numbness, neuralgia, irritability, trembling, powerlessness, soreness, coldness, stiffness, and so forth, this disease can be treated as satisfactorily as almost any other form of nervous disorder; and, even when cramp or spasms of the muscles have appeared, it may be entirely cured.

In the later stages, after the symptoms have existed for years, the malady may become absolutely hopeless, even though the patient abandon his occupation. I have seen cases that have been afflicted for over a quarter of a century.

One striking case of this kind I had opportunity to see through the courtesy of Dr. W. C. Wey, of Elmira, N. Y. Both hands were affected, and the numbness and powerlessness were so marked that sometimes a newspaper that he was reading would drop to the floor. The whole body seemed, indeed, to have been disturbed, and he had been obliged to give up his position as cashier of a bank.

In all these cases, the prognosis is better in nervous and delicate patients than in those who are phlegmatic and strong.

Eighthly and lastly.—The treatment of writer's cramp and affections allied to it consists:

1. In the use of electricity locally applied. Both galvanic and faradic currents may be used—preferably the former. In some cases galvanization of the spine and neck, and what are called spinal-cord nerve-currents, are indicated. Strong galvanic currents, with metallic electrodes, I have used with advantage in some cases where mild currents seemed to do no good. The wire brush with the faradic current I often use, and in some cases electro-puncture.

The relief of pain and fatigue that follows these electrical applications is immediate and uniform, and most grateful to the sufferer; and this temporary effect can be obtained even in the worst cases. I have not yet been able to demonstrate any very marked advantage from the rhythmical movements of the muscles in connection with the electrical applications.

2. Hypodermic injections of atropine, strychnia, duboisia, Fowler's solution, and other tonics, narcotics, and sedatives. These remedies need often to be gradually pushed to their physiological effects. Electricity and hypodermic injections combined have made an epoch in the treatment of writer's cramp. The evil effects of hypodermic injection are guarded against by care in preparing the solutions, by dilution of irritating substances, by moderately deep puncture, and by substituting other treatment in those cases where, from any constitutional tendency, suppuration is easily excited.

3. The internal use of calabar-bean, ergotine, iodoform, and in some cases of nerve food, as oil and fats. It is useless in the majority of severe cases, to dally with mild remedies or ordinary tonics.

4. Massage, or systematized kneading and manipulation of the muscles, with friction, and pinching, and pounding of the skin, and passive movements of the joints, large and small.

Dr. Douglass Graham, of Boston, has used this method with very encouraging success. I now employ it in all my cases. The whole arm should be treated.

5. The use of dry heat and dry cold, by rubber bags containing hot water or ice. These may be used alternately.

* Read before the Medical Society of the State of New York, Feb. 5, 1879.—*Medical Record.*

† Ataxy, for example, was formerly diagnosticated by inability to stand with closed eyes, by the ataxic gait and by the electric pains; and more recently an unsuccessful attempt has been made to prove that the absence of the tendon-reflex is a sure sign of that disease. There was no need of experiment to disprove this claim; the physiology and pathology of the nervous system are now in a condition, where we are able to prove deductively—without examination—that all such claims of pathognomonic symptoms, however reliable they may be as aids and accessories, are illogical and unscientific.

* Transactions of the London Medico-Chirurgical Society, vol. lxi.

6. The actual cautery and very small blisters to the upper portion of the spine, or along the course of the affected nerves and muscles.

Rest alone, even long abstinence for many months from writing, will not cure writer's cramp, as has been proved by the experience of many cases. The best results I have ever had have been made with cases that kept right along with their occupation—although avoiding excessive work—with the aid of mechanical appliances.

Among the hygienic devices for the relief and cure of writer's cramp are the following:

1. The device for holding the pen—a ring pen-holder—so as to relieve the thumb and fingers. An excellent arrangement of this kind has been perfected by one of my patients. By this contrivance the thumb is allowed perfect rest, and the index finger and second finger are united by rings so as to make practically one finger, which is attached to the pen-holder. The over-use of the muscles most liable to be involved in writer's cramp is thus avoided. The gentleman who perfected this ring pen-holder was himself substantially cured of a bad form of writer's cramp by its use in connection with electrical and other treatment, as above described. He is a book-keeper, and can now follow steadily his occupation, although troubled at times with symptoms of weariness. He kept right on with his occupation during treatment.

2. The type-writer. This instrument is destined to be of great practical service to writer's-cramp sufferers, as well as to those who, though not having the cramp, are made nervous and locally tired by the mechanical labor of writing. During the past year I have made many experiments with this instrument, and studied carefully its relations to the nervous system, in order to determine these points. Unfortunately, book-keepers and those who write very short notes or messages and signatures cannot profit by the type-writer; but for those who write continuously the instrument is an almost perfect relief. After some instruction a reasonable degree of skill in its practical use can be obtained during the play-hours of two or three months.

Thurber's kaligraph, now almost forgotten, was an ingenious contrivance for writer's cramp-sufferers; but it is now superseded by the two inventions just noticed.

3. The use of large pen-holders, so that the muscles may be less restricted; fastening a piece of sponge to the pen-holder, so as to relieve the pressure of the fingers. One of my correspondents writes me that he used this device for a year.

4. Holding the pen between the different fingers, thus relieving the thumb and index finger. One of my medical friends finds great relief by this device.

5. The use of quills and very flexible pens, and pens with very broad points, so as to run easily like quills. Some pens have been sent to me from Germany that are made with this special object in view. The use of the lead-pencil is also a great relief. The mica pen and the Esterbrook stub-pen are worthy of trial.

6. Frequently changing the pen and the pen-holder and style of pen, so as to change the mode of action of the muscle. Dipping the pen for ink is usually regarded as an evil, but it doubtless saves many of us from writer's-cramp.

7. Changing the position in writing, as from sitting to standing, or holding the paper in the lap. These methods of relief are to be commended, especially for those who are just beginning to have the symptoms of the disease, who are yet in the stage of exhaustion. It is a mistake to always try to point the pen toward the right shoulder. When utterly tired out, it is well to stop entirely.

8. The avoidance of faulty and painful methods of writing, and the study of easy, natural methods. A person who writes a cramped and stiff style, no matter though it be a legible one, is a fair subject for attack, especially if writing occupies most of the time. This factor is of great importance. An eminent author and journalist is accustomed to put his pen in the pen-holder at an angle of several degrees backward, and thus is able, as he tells me, to write consecutively over forty words a minute.

9. Writing with the left hand. Out of eighteen cases that tried this plan, three failed utterly, six were partially successful, and nine were completely successful. In the six partially successful cases the disease either appeared in the left hand, or after a time showed a tendency to appear there. At the beginning of the disease, educating the left hand may be of itself sufficient for a cure.

10. The use of various gymnastic and athletic exercises, as rowing, paddling, and so forth. In some cases the sufferers are unable to do many other kinds of work; carrying bundles or turning door-knobs hurts them just as writing does; but such cases are exceptions.

Speed of Handwriting.—In the study of this subject, I have made many experiments with a view to determine the average speed of handwriting. I find that between twenty-five and fifty words are written in a minute by those who are accustomed to write, the average being perhaps about thirty words when no time is lost in thinking or dipping the pen.

The method of experimenting that I have adopted is, to have the subject experimented on write something with which he is quite familiar—words of all lengths—for one minute. Practically, no one writes steadily as fast as these experiments would indicate, for, after a few moments of writing at the very top of speed, there will come to the majority a weariness; then the delay of composition also interferes.

These experiments were made with lawyers, physicians, clerks, book-keepers, scientists, and men of letters. Mr. T. A. Edison, the inventor, is also an expert in handwriting, and I have made with him a number of experiments in order to test the rate of speed of different varieties of penmanship. When he writes slowly and with care—from fifteen to twenty-five words a minute—Mr. Edison's handwriting is phenomenally clear and beautiful, resembling copper-plate printing, not in a flowing, but in a cramped hand, the letters being often separated as in print. When he rises to forty words a minute, the writing is still more cramped and less beautiful, though yet legible; with forty-nine words a minute, his writing is quite illegible.

I find that journalists write with a lead-pencil—which, as a class, they generally use—from forty to fifty words a minute. Experts on the type-writer, according to my experiments, can print for a short time at dictation from seventy-five to one hundred words a minute; but in practice, very few of those who use the instrument put down on the average more than half that number.

A number of years ago a man attempted on a wager to make with a pen an enormous number of up and down strokes—a million, I believe, within a month or less time. Swelling of the hand and wrist, with severe pain, so annoyed the experimenter that it was necessary for some one to stand near him and pour on cold water and apply various lotions. In this cramped and continuous movement and tension of muscles is found the philosophy of all these forms of professional cramp. I have made some experiments with myself in order to ascertain just how many single disconnected up and down strokes I could make with a pen; and find that from 175 to 200 a minute is about the limit, and very soon the hand becomes wearied. A friend of mine, connected with the surrogate's office in this city, tells me that the clerks in that department sometimes complain of swelling of the wrist from over-writing.

Mr. Edison, whose amazingly fertile mind is constantly making original suggestions even in departments quite remote from his own, showed me not long ago the following fundamental experiment. A small rod of steel or iron, or other hard substance, about one-third of an inch in diameter, is held very firmly between the thumb and forefinger of the left hand; very soon there comes a pain in the abductor of the thumb, which may be unbearable. This position is a familiar one to manufacturers of electrical apparatus, since it represents their method of winding wire on bobbins.

Telegrapher's and musician's cramp.—The above practical conclusions in regard to treatment apply to the other forms of professional cramp, as that of telegraphers and musicians—violinists, organists, pianists, and harpists; also to the cramp of artists, painters, engravers, and sewing women.

Telegraphic operators have two forms of cramp—the ordinary writer's cramp, from receiving and writing out messages; and true telegrapher's cramp, from striking the index finger on the sending instrument. The malady is quite a common one among telegraphers; and an attempt has been made to reduce its frequency by the use of a rubber cap on the button on which the finger presses in sending. This device is, I understand, but partially successful.

Musicians, when afflicted with cramp, have the same symptoms as writers, and are likely to suffer in both hands, although one hand may be affected quite differently, from the other. In one case that I saw through the courtesy of Dr. Webber, the right hand, on beginning to play, showed contraction of the muscles of the thumb and index finger, with a tendency upward; while in the left hand, at the same time, the second and third fingers were firmly fixed into the hollow of the hand, so that they could be opened only with great difficulty. In a case now under my care, the right hand is affected in precisely the same way, while in the left hand the little finger only is disturbed. This form of trouble often comes from stretching the hand in playing octaves.

In another case the third finger of the right hand is raised involuntarily while playing; and in an organist now under my care there is simply stiffness and pain in the interossei between the third and little finger, and anæsthesia of the back of the hand. In the case of a very eminent violinist the muscles of the left arm and forearm, and also the fingers, were so weak and exhausted from long holding the violin in position, that he had to abandon his profession.

I have succeeded in curing a long-standing case of pianist's cramp, where the symptoms seemed to depend on a neuritis, excited originally by exposure to cold in bathing, and made worse by severe practice at the piano. In this case there had been great uneasiness, and even severe pain after playing, and he had abandoned his profession. He is now able to play several consecutive hours without fatigue.

AGRICULTURAL PLANT FEEDING.

IF we assume the use of seed of the best variety grown, and the exercise of the proper intelligence in the operations of culture, and seasons favorable on the average, what are the true methods of plant fertilization for the farmer to pursue?

All experience says, To feed the plant. But how? In the haphazard way so common throughout the land, of putting on a given amount of dung, the complete fertilizer of the farm, of buying so many pounds of superphosphate to apply to the soil, of using muck, or salt, or marl, or any of the numerous substances of commerce, without regard to the effect that it is desirable to be produced, or without reference to the value of the crop and the application? The practice which is to bring success to the farmer is that one which brings certainty with use; which reduces waste to the minimum; which allows of the largest net profits; which renders the farmer independent of home resources which are fixed in their amount.

The plant feeds upon the soluble material in the soil, of which but three elements, as we have noted, require to be supplied; and very probably in most instances but two, nitrogen and phosphoric acid. The former in our agricultural condition passes readily through the soil with the soil water, and thus can readily come into contact with the feeding surfaces of the plants—the roots—and can in the presence of a sufficient rainfall be washed from the land and wasted. Hence, nitrogen is not available to the plant to the extent of its supply, except under certain conditions which include its retention in the soil, and its presence in contact with the roots. It feeds also on soluble phosphoric acid, and this is so firmly retained in the soil that it does not practically escape, but, on the other hand, it changes its form and becomes unsuited for plant food. It is also held so firmly by even thin layers of soil that it is with difficulty caused to permeate the extent of the root-pasturage of our plant. Hence, difficulties in the practical use which require a careful study and fitness of conditions in order that the plant shall receive this food and return it again to the farmer.

As farmers, we are concerned with the science of plant fertilization as interpreted from the standpoint of practical farming, and all these points we have suggested are of a direct importance to the farm practice, and may be iterated, as convenient, with advantage to the subject, however their relations to the writer.

Agriculturally speaking, the plant feeds from the soil. Through the agency of the roots, it absorbs soluble material from the soil interstices, and transfers this material to its various destinations, where it becomes manufactured through the agency of the plant life into organized material. It is, therefore, only the soluble matter of the soil, and that which comes into contact with the rootlets, which is directly available to the plant. Hence—and here is a most practical conclusion—of the fertilizing material supplied to the plant, only that which is directly brought into contact with the plant is immediately available. In the application of dung, a bulky substance, the effort of the farmer must be to thoroughly incorporate with the soil, so as to secure all the chances possible for contact with the roots. To just the extent that this is accomplished, is the efficacy of dung as plant food. Thus, to illustrate: In Mr. Lawes' experiments on wheat for a series of years in the Broadbalk field at Rothamstead, the field received fourteen tons of barnyard manure each year, and yielded an average annual crop of 35¾ bushels of wheat for the first twelve years, and 35 bushels for the second twelve years, the unmanured portion giving 12¼ bushels and 12⅜ bushels respectively. Now the first year of trial, the increase was but 5 bushels; the second season, 9 bushels; the third season, 9 bushels; the fourth season, 13 bushels; the fifth season, 11 bushels; the sixth season, 12 bushels; the first twenty years, 16 bushels; the twenty-four years from 1852–1875, 20 bushels; the thirty-two years from 1844–1875, 18½ bushels; all of which goes to show the time required for the full effect of the application to be felt on the land.

If we take the analysis of dung, we find the following correspondences between the application of fertilizing element and the removal in crop's increase—

Annually applied in dung.	Annually removed in crop's increase.	
	grain. 18½ bus.	straw. 282,110 lbs.
Nitrogen.....144 lbs.		28 "
Phosphoric acid. 93 "		14 "
Potash.....217 "		16¼ "

Assuming what is not the fact, that the straw bore the same proportion to the grain the first season as afterwards, we would have for the first year the removal of but 5-18½ or 10-37ths of the amount of fertilizing element as shown in the table, from the first year's application.

What conclusion, then, must we draw from this statement? First: That in round numbers, a ton of ordinary barn manure is equal to the production of about one bushel of wheat (really in this case 15·6 tons of first-class dung produced 18½ bushels of wheat, or 1·2 bushels per ton.) Second: That under the conditions that exisited in this long experiment, but about 1-5 of the nitrogen applied was recovered in crop increase; but about 1-7 of the phosphoric acid; and but 1-13 of the potash. Third: That it is only through the continuous application of the dung that the maximum effects were reached.

Let us suppose now that these elements of fertility that we have considered were applied in a form in which they would come more readily in contact with the roots, as in artificial fertilizer form. We have in Mr. Lawes' exhaustive experiment materials to ascertain this point also, and here is what is shown on the same field:

The application was 400 lbs. ammonia salts, 392 lbs. superphosphate, and 200 lbs. sulphate of potash. The crop increase was 18 bushels the first twelve years; 19 bushels the last twenty-four years, the average increase being 19⅜ bushels of grain, and 2,324 lbs. straw for the last twenty-four years, and about 10 bushels of grain, and 1,827 lbs. of straw. Let us form a new table wherein we can compare the relative amounts of fertilizing substances applied removed with the crops, taking the last 24 years for our figures.

	Applied. In dung.	Applied. In chemicals.	Recovered in increase. From dung.	Recovered in increase. From chemicals.
Nitrogen.....144 lbs.		90 lbs.	32 lbs.	29 lbs.
Phos. acid ..... 93 "		65 " (?)	6¼ "	6¼ "
Potash . .....217 "		100 "	18½ "	17¾ "
	Proportion recovered. From dung.		Proportion recovered. From chemicals.	
Nitrogen .....22 per cent.			32 per cent.	
Phos. acid..... 7 "			9¼ "	
Potash... ..... 8¼ "			17¾ "	

A table showing the advantage to be gained from the use of chemicals in wheat growing over the same materials supplied in dung, and owing in large part to the difference of form as influencing bringing into contact with the absorbing roots.

In conclusion, we find it unmistakably evident that not manure nor fertilizer, as names, concerns the farmer, but the getting of plant food to the plant, and that the form in which plant food occurs is worthy of our careful consideration.—*Scientific Farmer.*

TREE CULTURE.

THE Secretary of State has received from T. B. Baker, editor of the Topeka, Kansas, *Commonwealth*, Assistant Commissioner to the Paris Exhibition, his report on forestry, which instead of including a bare narrative of forest products, implements of forestry, etc., at Paris, gives in concise form the general information derived from an examination of the exhibits of this class, and also a general idea of the system by which in European countries, under difficulties unknown in America, the signs of forestry have been fostered, protected, and well-nigh perfected. The report says the time has happily passed, it is to be hoped, when throughout the United States trees are considered incumbrances of the soil, to be got rid of by the most wasteful and destructive methods possible. There is now as much anxiety felt for the reforesting of our bare hillsides as once was felt for stripping them of the last vestige of covering.

Yet when our people consider the area thus deforested, and in addition the vast prairies of Kansas and other Western States, themselves treeless, and creating in the course of settlement a demand for the destruction of countless acres of the fine forests of Wisconsin, Michigan, and Minnesota, the American unacquainted with any system of forest culture, unaccustomed to any State or Federal legislation on the subject, is apt to exclaim, "Who is sufficient for these things?"

EXHIBIT OF WOODS.

The report here contains an interesting review of the forestry exhibit made in the Challet, near the administration of forests at the Trocadero, and in the construction of which 500 varieties of woods grown in France were used. Also, containing the geological and entomological collections made by the school of forestry, and models representing the reforesting of mountains. This exhibit was extremely interesting in all its details, showing the transformation of bare rocks into thrifty wood-lands.

Next to that of France was the exhibit of the botanical division of the department of agriculture of the United States, including sections of the principal forest trees (three hundred pieces) and flowers. The Oregon State exhibit included a cabinet composed of twenty-five thousand pieces of wood from her own forests.

FORESTRY LAWS IN FRANCE.

As early as 800 A.D. the first steps to protect the forests of France from destruction were taken. In 1290 an ordinance was passed under which a corps of officers in charge of forests was appointed, and in 1669 Louis XIV. codified the entire system of laws and took measures to protect the interests of the kingdom menaced by the destruction of the forests. Every mountain was administered by masterships, and the woods of private persons themselves were subjected to restrictions judged indispensable to assure their preservation. The hunt, the fishing, and in fact everything pertaining to the administration of forests were also confided to the vigilance of officers of the masterships.

This superior right of protecting forests whose preservation has, from all time, been recognized as necessary to the existence of civilized society, has been claimed by all governments which have succeeded ancient monarchy in France.

In 1801 the woods and forests were divided into twenty-seven conservations. At the present time the forest department is one of the principal bureaus of the French government. There are forestry schools where pupils are trained in all the sciences. The graduates are compelled to serve as foresters. The same discipline prevails as in the army, and the profession of forester is as much so as an officer in the army.

There is a list of penalties for injuring trees, scaled according to the class, the first class consisting of oaks, beeches, yoke elms, elms, ashes, maples, pines, fir, larches, chestnuts, lote trees, walnuts, service or quick trees, and other fruit trees; second class, alders, birches, aspens, poplars, willows, and other species not comprised in the first class.

THE PENALTIES

for cutting or carrying away, with aggravating circumstances, that is to say if the offense has been committed in the night time, or with a saw, or by a delinquent who has been guilty of the same before, or if the offense has been committed by a delinquent with the aid of a saw who has been guilty of the same offense before, the penalty is fine and imprisonment. The forests of France comprise 9,187,304 hectares, of which 967,118 belong to the state, 2,090,788 to the communes, or parishes and public institutions, and 6,129,398 to private parties. The statistics of consumption show the value for all purposes in 1877 to have been $40,000,000.

THE CORK OAK.

As the cork oak can be cultivated in the United States, the report says that it grows in Algiers, in Corsica, Spain, and Southern France. At fifteen years the tree furnishes a coarse oak, from which buoys and Spanish black are made. The cork, which is collected every ten years, is of good texture. Forty parishes are occupied in the manufacture of corks, and the demand is constantly increasing.

SWEDEN AND DENMARK.

In Sweden the forests are under immediate administration of the state, and increases year by year by the purchase of private forests or their separation from farmed state lands. In 1876 the public forests gave a net receipt of 1,093,479 crowns. The forests are under the skogstymisen of the Finance Department, and under the direct care of employes and agents of the forest service. There is a high forest school in the Royal Park at Stockholm, with professorships of forest economy, natural history, chemistry and physics, forest legislation and administration, and political economy. There are forty pupils, of which eleven are Norwegians and three Finnish. The institution receives 21,300 crowns. Sweden depends almost entirely upon its forests for the fuel necessary for its metallurgical industry. The revenues of the forests of Sweden realized 165,000,000 crowns, about $46,000,000. In Denmark the revenue of the forests is estimated at 40 francs a hectare and a total of 7,000,000. The state forests yield 17 francs a hectare. In the last century the forests of Sweden were owned by private proprietors and suffered a wasteful destruction of trees, which the state laws are now remedying under the direction of royal decrees and royal officers.

PORTUGAL AND SPAIN.

The forest service of Portugal is both administrative and technical. The pine forests of Leiria, the resin manufactory and the forest of Busaco, are under a special direction. In Spain the forests receive special attention; the conditions of climate and the prosperity of the people being so dependent upon forest vegetation that the Royal Government has taken charge in order to prevent the denudation of the mountains and the depopulation of the country. The forest administration in Prussia forms, as in France, a division of the financial department, with a director and a council of headmasters and corps of inspectors. There are also forestry brigades and guards, under rigid discipline.

OUR OWN FORESTS.

In its conclusions, as affecting the United States, in which there are 380,000,000 acres of wood land, the report says: The people of the United States have, up to a comparatively recent period, been famous destroyers of the forest. It is a significant fact that the American ax takes precedence in the markets of the world, and that the American chopper is the most expert axman. Thousands and thousands of acres of noble forest trees have been destroyed merely to rid the earth of them. The Western pioneer passed his life in the toilsome labor of chopping and burning trees which his descendants would gladly replace if they could.

Of later years a growing public sentiment has sprung up in favor of the preservation of trees, both for ornament and use. The evils of forest destruction are now admitted, though our practice is not always in conformity with our theory. The practical question is, What can we do to preserve and restore our forests, to repair the waste of the past, and provide for the future? Governmental interference is a resource to be used sparingly, for the reason that it is not, as a rule, efficacious. There has existed for many years a statute against cutting timber on government lands, and it is safe to say that few statutes have been more persistently violated. In newly-settled sections few people see anything wrong in cutting government timber, especially when used in the development of the country. The timber-cutter's act has been more effectual than repressive legislation. In this the government holds out substantial inducements for the cultivation of trees, offers itself as the patron and encourager of forestry, and thus fosters a popular sentiment in favor of tree growing.

"ARBOR DAY."

The device of an annual "Arbor Day," originating, I believe, in the State of Nebraska, has filled many Western cities and towns with beautiful shade trees, at no cost to the Government, Federal, State, or municipal. "Arbor Day" has been added to our scanty list of public holidays; young and old join in the cheerful labors of the day, and school and religious societies are conspicuous in its observance. In one day in Topeka, the capital of Kansas, more was done in beautifying the grounds belonging to the State by the free and voluntary labors of the citizens than had been done in years under the authority of the Legislature, and at an expense of several thousand dollars of the public money.

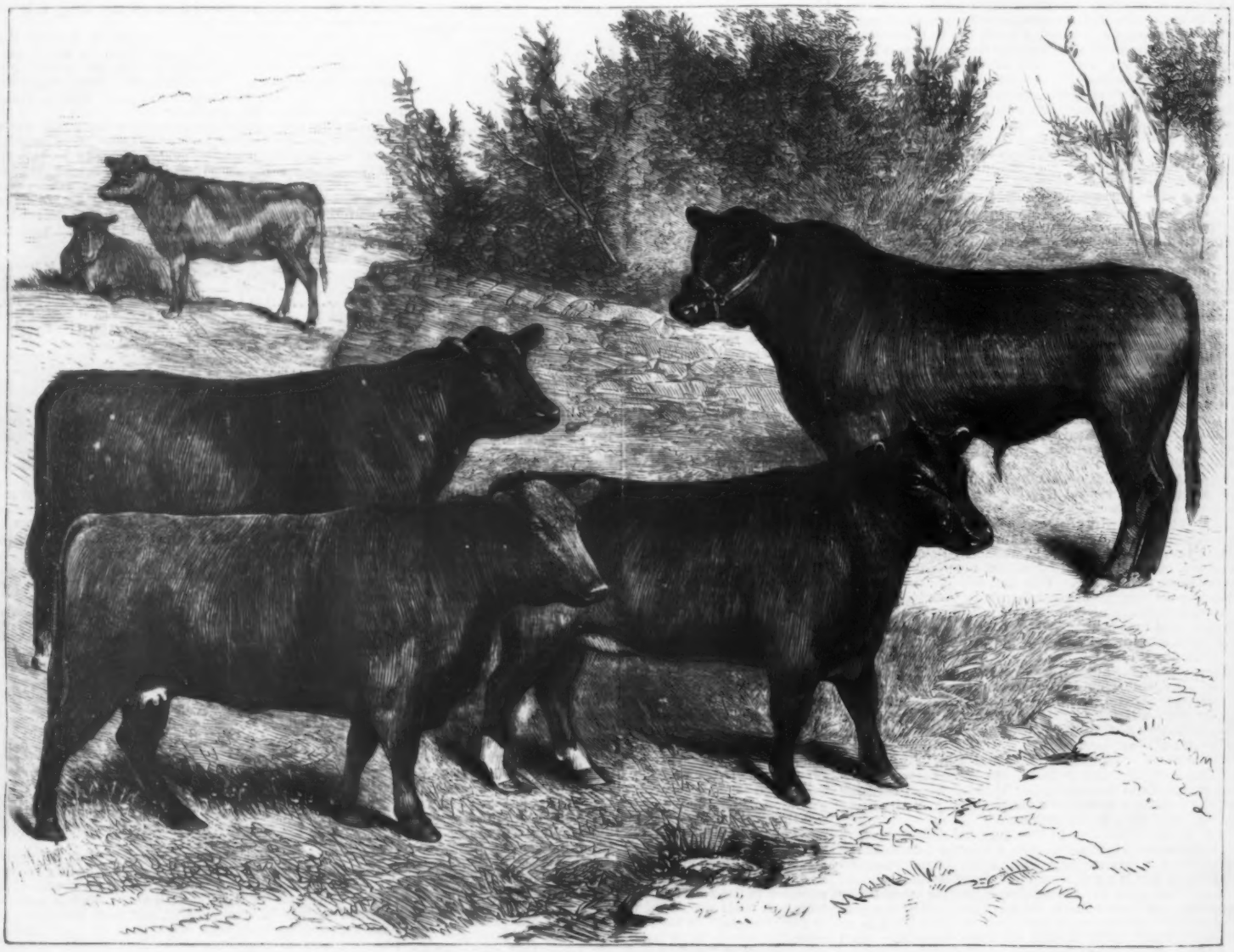
NEW WAY TO SOW GRAIN.

SOME of the more progressive farmers of California rig a seed-sower behind their plows in such a way that although they plow from 8 to 10 inches deep, yet the grains of wheat fall just in time to be caught by about 2 inches in depth of the lap of the furrows.

A writer for the San Francisco *Bulletin* says that large fields treated in this way, near Woodbridge, now present the prettiest sight imaginable. The long rows extend in straight lines across the fields, evenly and in a fine state of growth. In ordinary seasons it is not considered necessary to harrow after sowing in this way if it is on summer-fallowed land.

ABERDEEN CATTLE EXHIBITED AT PARIS.

THIS engraving, which we take from *Land and Water*, represents the champion group of polled Aberdeen cattle exhibited at the Paris International Exhibition last year by Mr. McCombie, of Tillyfour, late M.P. for West Aberdeenshire, who has been a famous exhibitor at both national and inter-



ABERDEEN PRIZE CATTLE AT THE PARIS EXHIBITION.

national shows since 1860. In some senses this Paris Exhibition was a peculiar one. Not only did it attract, as an international contest, the competition of all countries, but it presented in its system of a special group contest a novel and peculiarly testing trial of the comparative merits of the breeds of all countries. Consequently its results were eagerly anticipated by all interested in stock and agricultural pursuits, and certainly the Parisians were very highly surprised thereat. On the second day of judging, when all nations entered for the championship prizes or objets d'art of a hundred guineas' value respectively, Mr. McCombie swept the field, gaining not only the £100 prize for the best breeding group in the foreign section, but also the £100 prize for the best beef-producing animals in the entire Exhibition.

ALLIGATOR PERFUME.

THE writer of the article descriptive of the Florida alligator, recently given in our SUPPLEMENT number, makes this addition:

I omitted, in speaking of the alligator, to mention the strong odor of musk he is capable of giving out. He has four glands that secrete this musk, two on the lower part of the head immediately under the throat, and two more, one each side of the vent. This musk is a thick whitish yellow fluid, and is precisely in odor like the musk sold by our perfumers. In stirring up a nest of alligators, one is often reminded of an apothecary's shop.